Tappi

PUBLISHED BY THE TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY

NOVEMBER 1954

VOLUME 37 · NUMBER 11

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For high wet-strength at an economical cost, more and more paper and board mills are specifying Hercules Kymene.®

Ready to use, easy to handle, Kymene is available promptly no matter where you are located. This popular cationic urea-formaldehyde resin has excellent stability in dilute solutions and has been proving its value wherever used.

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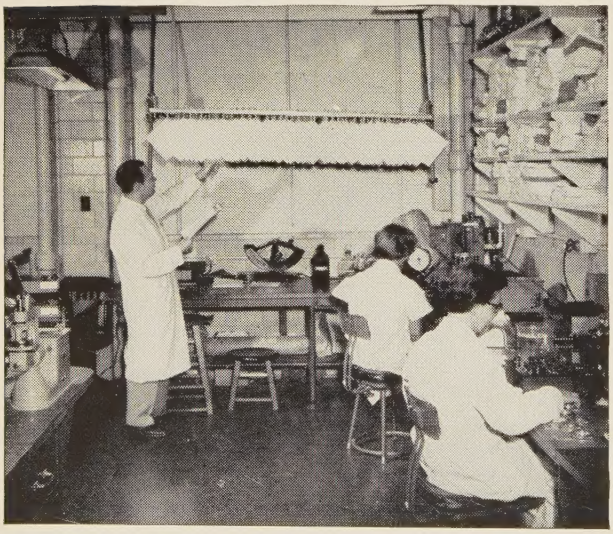

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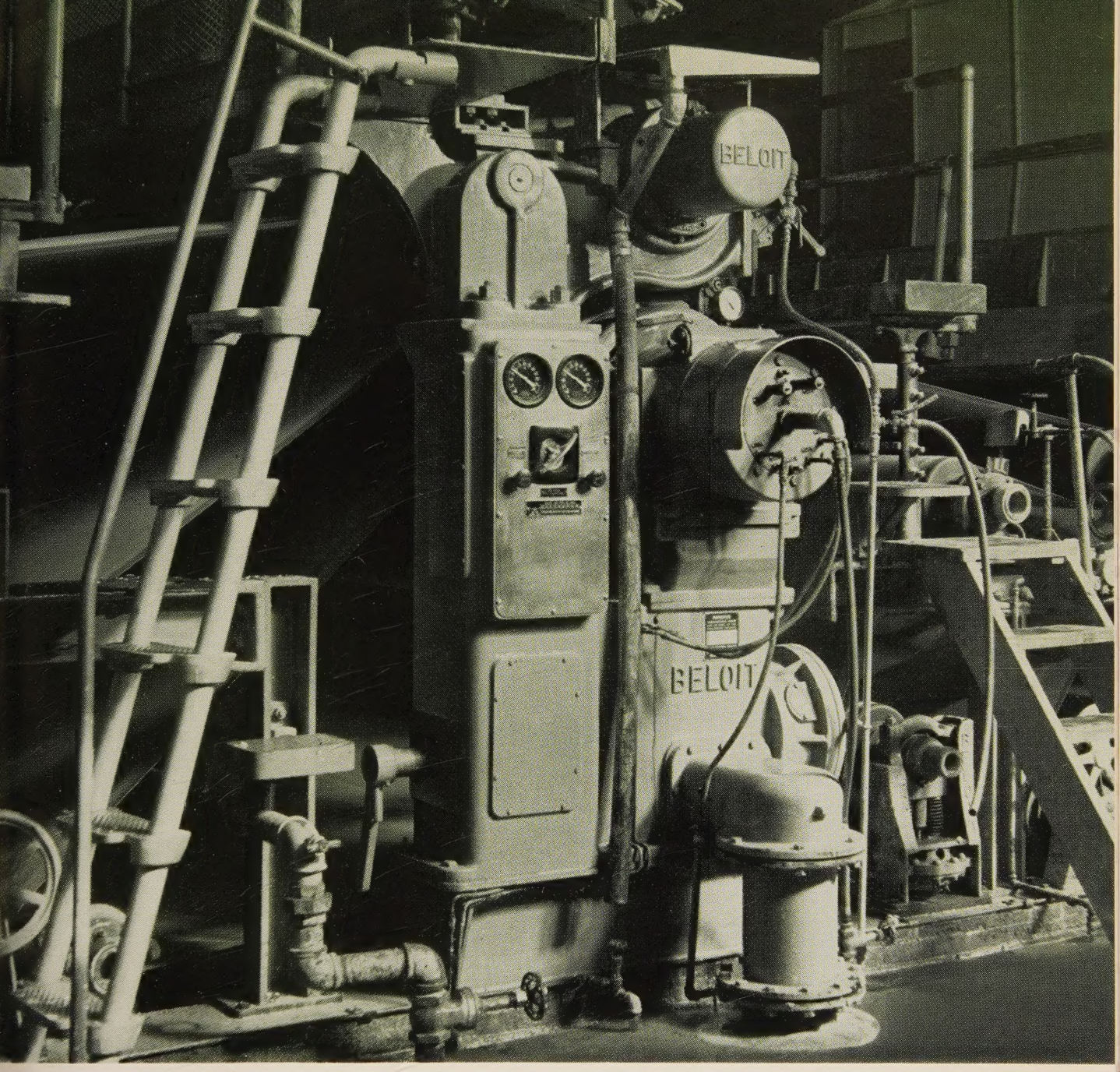

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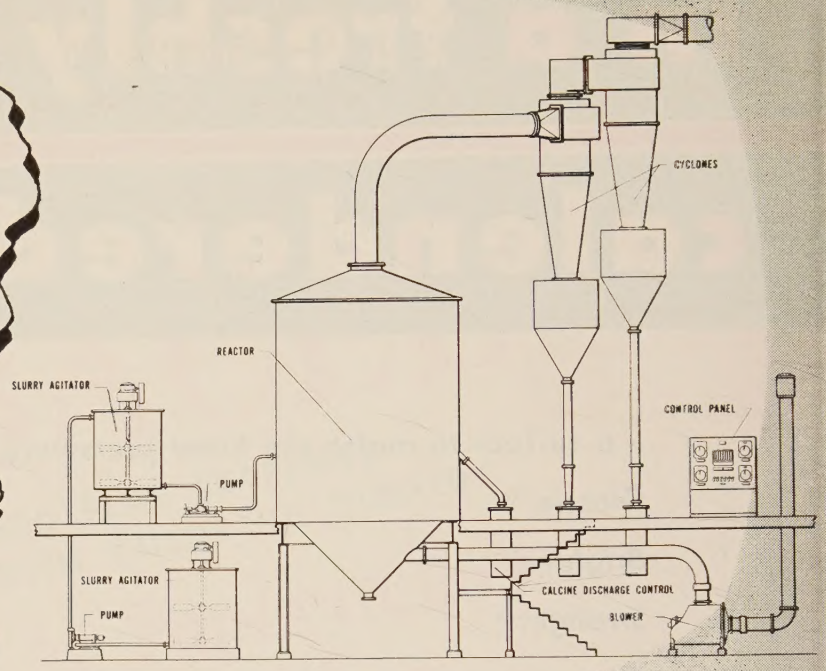

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NOVEMBER 1954

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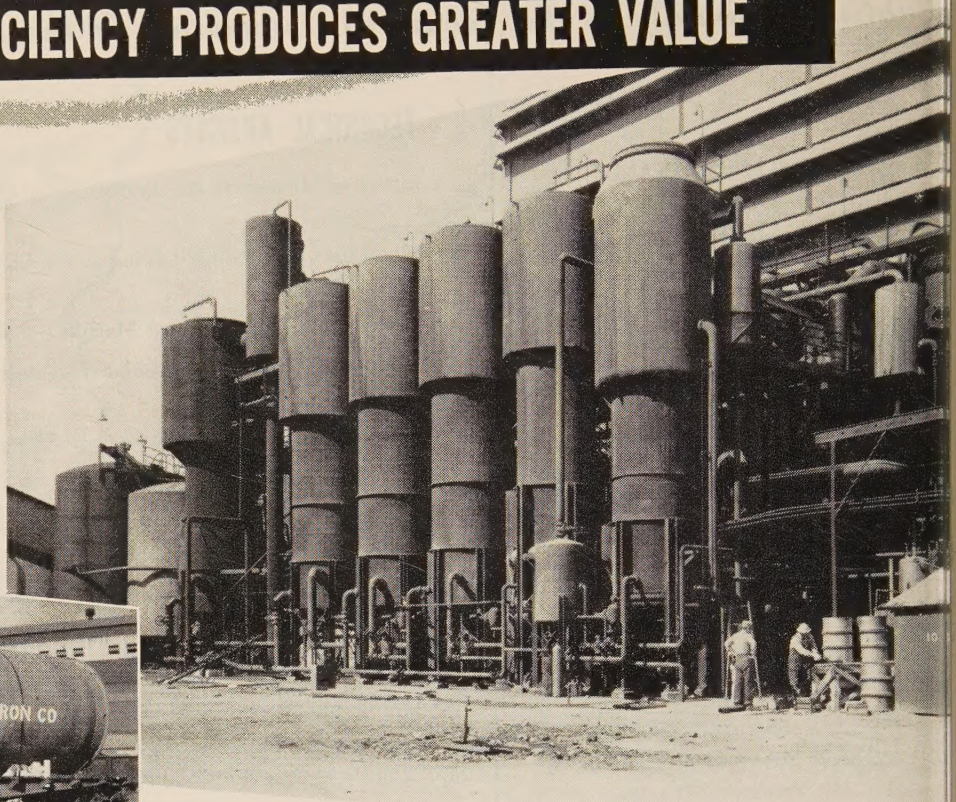
Right: Conkey Integral Sextuple Effect Evaporator set out of doors at a Southern pulp mill.

Below: One of six 12-ft. diam. by 45-ft. 4-in. digesters Chicago Bridge & Iron Company built for the St. Joe Paper Company at Port St. Joe, Florida.



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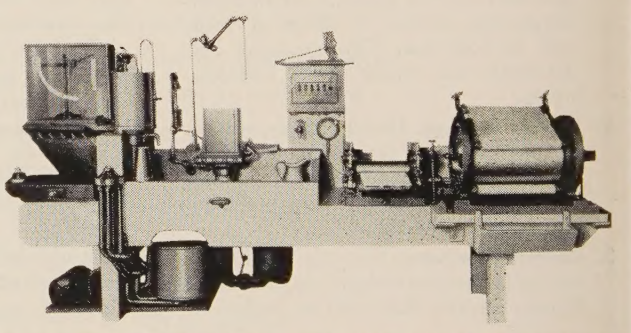

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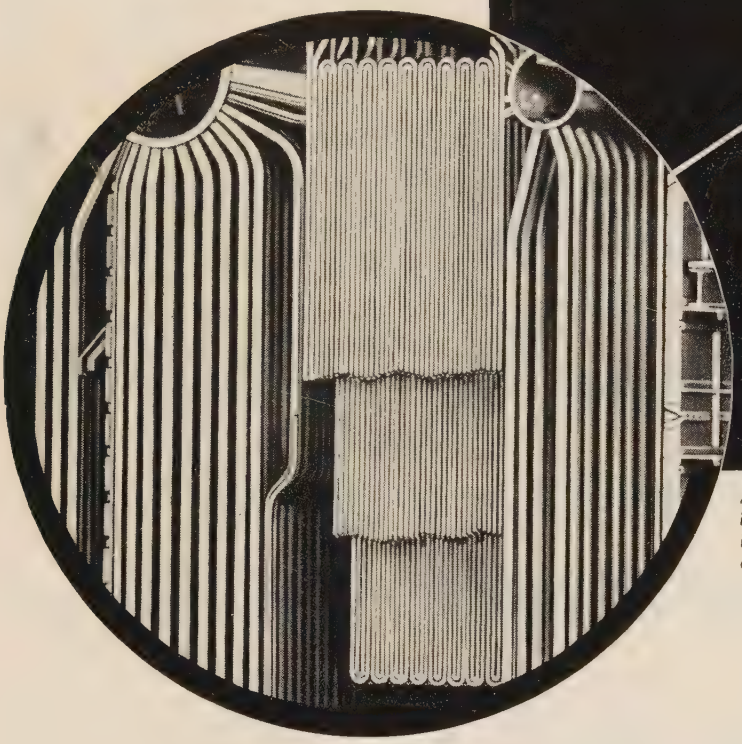

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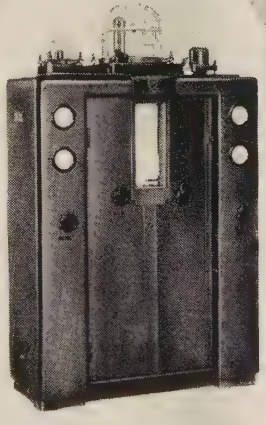

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WE'RE WORKING WHILE ROME BURNS

J. Q. du PONT

J. Q. du Pont

"We're Working While Rome Burns!" If any of you suspect there is a catch in this title, you're right. If any of you came here to hear yourselves and your fellow American business leaders "patted on the back" for your fabulous production and other material accomplishments, you're wrong.

But don't get me wrong, either, on this! I have the deepest respect for production and, more importantly, for those who can and do produce.

Production! Whether it be growing one little potato crop to feed a hungry hermit, or a vast wheat farming operation to help feed a nation, these things I have always, and deeply, admired.

Indeed, perhaps the most complete error any of you can make about my words today is to assume I have anything less than the highest regard, and deepest gratitude, for those great and small "good doers," good producers, good executives and administrators, good pay-envelope-fillers who, collectively, form much of the brains and backbone of our American business structure today.

But, just as there is honor and reward and respect for material effort and accomplishment, especially production as we know it here in the United States, so also is there a dangerous pitfall. And this pitfall is dangerous precisely because we are working so hard. "We're Working While Rome Burns." And I would like to remind you that that, sometimes, can be worse than fiddling while Rome burns.

"Fiddling," in this sense, is not a very absorbing occupation. It is a pastime or diversion. It's easy to drop such "fiddling" and "run to a fire." It's easy to stop "whittling a stick" to assist in some true and general emergency. But, when you are working, ah! that's a different story, indeed!

There is a challenge in work, in almost any good work and a deep, almost sensual, gratification, or thrill, in watching our efforts materialize, in "seeing our gardens grow."

There is a passionate pull, like some great magnet, drawing us on and on, if we're working, not fiddling. And this is especially true if we're doing something urgent or important, like our present national defense program.

There is an almost complete absorbing power about good urgent work that makes us deaf to "the call for supper" that makes us blind to the awful "handwriting on our wall."

There are exceptions, of course! I'm not so stupid as to contend that American business is entirely asleep to the threat of final despotism either here or abroad. Indeed, as one whose job it is to travel endlessly and read much, in this present awful battle for men's minds, I'm happy to report that great strides have been and are being made by small, medium, and large American business and professional men in taking up the torch of liberty and freedom against government by edict, whether it be in Moscow, in Argentina, or where-have-you.

But, and here's my first pitch, I submit that far too many leaders of American business are dangerously engrossed, yes, almost hypnotized by this passionate reality called work—this voluptuous "Miss Production" who sits, not on the River Rhine like the girls of the Lorelei legend, but on the planning and control boards, and the assembly lines of American industry, combing her golden hair.

And leading us, innocently, of course, but leading us, cost reduction by cost reduction, research triumph by research triumph, dividend by dividend, pay increase by pay increase, slowly but surely, to the red rocks of destruction!

There is a way out of our dilemma. There must be a safe way up our "Rhine," and past these "rocks." But it will take more than full steam in our production boilers, more than sweating top performance by industrial research and technical men buried "blind" in the hold of our ship. It will take men, not "boys," on the bridge of our business boat. Men with keen and deliberate eyes who can see far into the darkening social curves ahead, and who can appreciate but not remain totally preoccupied with this beautiful siren, "Production," this wonderful wife, called "Work."

"Rome," our "Rome," is burning! These great and good, and once so boldly free, United States of ours are burning; burning with the challenge of World Communism and the threat of a world war too horrible for most of us even vaguely to comprehend. But this is not "news" to a group like yours. The point is, what do we do about it? What do far too many of us do (aside from applauding little speeches like this and sending copies of them around with friendly notes to each other saying, "This is must reading" or "Thought you'd enjoy this one too!").

What do we do? Why, we do a very natural thing, a forgivable thing, if it were not for the fact that this may be our last big throw at world dice—our very survival, not only as individuals, but as a species upon this planet.

What do most of us do when we hear the fire alarm of freedom ringing? Do we drop part of our work and

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grab for the fire hose of faith and ideals without which world slavery cannot be checked and then defeated?

No! You see, we're *working* not fiddling! Pat, pat on our back. And so, we simply press down harder on the throttles of production and sales as only Americans (I hope) can press those pedals. And in our absorption many of us in business and the professions turn a deaf ear to the national social, economic, and political "fire alarm." Some say, "Leave it to the clergy, the educators, the sociologists; that's their job."

And then there's another reason, if we are honest with ourselves. Many of us simply don't quite know how to step into this bigger field or battle for men's minds that we've got in America today. And so, as an escape from reality, paradoxical as this may sound, we turn back quickly to still more work, still more production of real goods! It sort of salves our consciences, I guess, to be doing something, making things we can see and feel in this confusing roar of thoughts and ideas and words that swirls about us these days.

We should, we must, take time off, each of us from this utterly important thing called "work" to do another equally important thing called "think." We must think about this fire of world communism and figure how to defeat it. And don't think that you can work and think at one and the same time! There are a few exceptions to this rule, too, of course, but, in general, deep thinking and great doing don't make good bedfellows. They can be, and should be, great partners, great teammates, but compatible bedfellows? No!

It is difficult, if not well nigh impossible, for you, or anyone else, to do concrete work and deep, or abstract thinking at one and the same time.

Take this speech of mine, for example. For more than a year I thought about it, dreamed about it, hoped about it. On railroad trains, as I rode from great city through great wood and farmland to other great cities, on airplanes as I looked down on this good and fertile land or ours, wondering what a despot and his horde of slaves will do with all of this, if! In the darkness of those most terribly awake hours of all, just before dawn, I've tried to put my fumbling fingers on the great curse, the weakest links, in our nation's chain (because the strong links have a way of taking care of themselves). I've tried to do this for you in my small but earnest way. If I have failed, that is beside the point. The point is that my *thinking* on this speech has been done in quiet, nonactive hours here and there, and now I'm doing it, not thinking it.

I believe many more of us American business and professional men must take time off from our good work to think about this problem of Communism and despotism. Then, having thought and thought deeply, we must devote a generous portion of our waking hours, and energy, to fighting in the battle for men's minds today.

Some of us can speak, "carry the work," "pass the ammunition," to the four corners of the land. Some of us can write speeches, plays, radio and television scripts and some of us, who can't do these things, can contribute in an important other manner by seeing to it that the truly effective writers and speakers on our side are handled wisely and utilized to the hilt, not wasted on "deaf" or snobbish ears.

But better still than any of these special efforts, we can all of us revise and improve our behavior, our actions, in the light of our deeper thinking. It is our actions, and what we are as business men, that will be our salvation or our defeat and destruction. Never forget, the man in the "house" (he used to be called the man in the street before television) is almost always a man of reaction, not action. Therefore, if we act decently, fairly, humbly, nobly, then this all-important "average man" will react favorably to us, to business and to management. Then, and only then, will he listen to our story. But if we do not behave, if we do not act properly, nobly, he will react against us and all, or most, of our public relations investment and effort is "right down the drain."

So much for this first observation about one pitfall of doing, of working. I hope I'm wrong. But too many things I've seen, and people I've met, convince me that I'm right in warning you "We're Working While Our Rome Burns!"

And now for my second observation, it also appears to me that far too many of those business and professional men who do "smell the smoke," far too many of us who do make the clear-cut decision to help fight the slow, hot fire of regimentation and slavery, make a very serious blunder right off the bat. And here it is: We start some kind of an advertising program or public relations effort. And we appeal almost solely to the selfish side, the material side, of those we would hold and those we would win over to "our side." I realize there are exceptions to this observation also. But, study the general record, read the speeches and institutional advertising, study the books, consider the radio programs, movies, television shows, yes, even the comic books that have been, and are being, used by "our side" in this great battle.

Consider these brave well-meant (and incidentally often very expensive) programs and efforts of free enterprise. See if you don't agree that far too many are still "slanted" to appeal only to the selfish side of their audience.

Listen to a few examples. I can almost say them by heart, I've seen them so often.

1. "Free enterprise has given you the highest standard of living the world has ever known!"
2. "You, Mr. Average American, have more bathtubs, more radios, televisions, etc., than 'seventy-two' Russians."
3. "Our way of life provides you and yours with more pay and more leisure."
4. "Free enterprise means more things, more happiness for you!"

Don't get me wrong. I realize full well the selfish side of man. (I like my bathtub and TV too!) It, the selfish side of all of us, is undeniable. And any sociological program that ignores the selfish side is courageous beyond words and often, in my estimation, crazy.

But, there is another side to man, to all of us, and it is the unselfish, the noble. Don't ever underrate it! Don't ever think it exists only in a few places. Those who do are either fools, or blind snobs, or pitiful babes in the woods of reality!

Thomas Carlyle put it this way. (I read this not so

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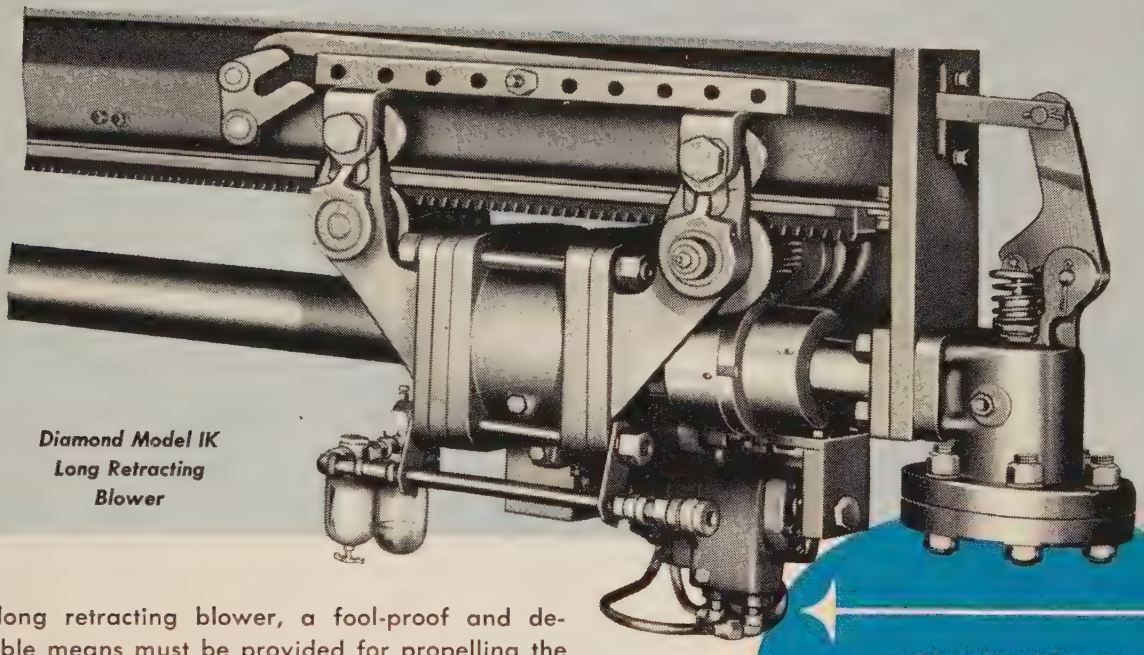

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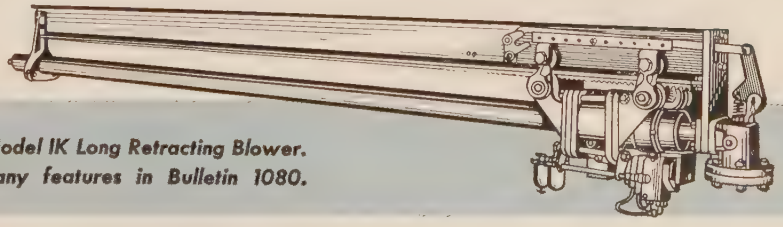

Diamond Model IK Long Retracting Blower. See its many features in Bulletin 1080.

long ago and I think it fits, or expresses perfectly, what I'm trying to say to you here.) "It is not to taste sweet things but to do noble and true things . . . that even the poorest son of Adam dimly longs."

Winston Churchill! Was he not shrewdly, and almost totally, banking on this badly neglected truth when he promised Britain nothing but "blood and toil and sweat and tears?" Think of it!

Death, not life; work, not leisure; sorrow, not happiness! These were the things that Churchill held out and up to Britain! And what happened? Was he booed, was he voted out of office, was his speech forgotten within a week, like most of our well-meant business speeches are?

Did Britain turn from him in this, its then awful hour? You know the answer. A nation was welded together almost as if by magic, and Churchill's words will live, perhaps forever! What was at work here? What human relations principles were involved? Well, of course, there were many. By the way, my wife, who has red hair and is a very practical person, was listening to me rehearse this talk not so long ago. Right at this point she cut in, as only one's severest critic can cut in, and said, "Wait a minute! There you go, off the deep end again! You've always had an excessive admiration for Churchill and, besides, you tend to let sentiment and emotion run away with you. Actually, I think, the reason Englishmen decided to join up and put their shoulders to the wheel for Churchill was not because of his fine words, but because they realized that if they didn't get together behind somebody, the jig was up and that England would be no more!"

Well, I'll admit my wife is about half right on this point. There is great truth in what she said. But certainly one big factor was this. The "dim longing," as Carlyle called it, of millions of big and little Englishmen "to do noble and true things," not to taste and enjoy material things, swelled up and helped stem the tide of fear and despair. I'm sure of this. Aren't you?

Let's drop now from millions of men and women in a nation at war, to just one little baby in its crib. You are "changing" it. For months now, since its birth, this very little and "lowly son of Adam" has been watching and feeling you go through the act of changing him: sometimes crying, sometimes smiling and cooing, but never, apparently, concerned with helping you.

And then, one night it happens! A fumbling little hand has finally learned how to grasp and hold a safety pin. And just as you need it, this hand, perhaps assisted by another equally clumsy one, holds up the pin and *gives it to you*—to use!

Nobility, the urge to contribute; nobility, the drive to give, not to take; nobility, the longing to do true and good deeds has been born, no, is unveiled, in your small child. From that day on, this "other side" of him, this unselfish side, will fight its unending battle with the selfish, or baser, side until that baby boy is an old, old man and dies.

There is nothing new about any of these ideas. The Greeks and Romans knew about this noble, unselfish side of man. So did the caveman in his dim way, except he didn't leave us very good records. Socrates, Genghis Khan, Saint Augustine, Shakespeare, Napoleon, Thomas Acquinas, Carlyle, Washington, Thoreau, Abraham Lincoln, Winston Churchill, great men like these, right down the ridges of time, have realized and and utilized this truth to the hilt. Some for better, some for worse, but all of them realized this duality, this doubleness, this selfish-unselfish, noble-ignoble, fine-yet base, nature of man. And the good of these great men, who led their fellowmen forward and upward, not backward and down, laid very heavy stress, depended most heavily, upon the *unselfish* side of their fellowmen, especially in times of national or other great stress.

Let us then not deny ourselves, deny our great cause, this almost miraculous factor in our present crisis! Business, I'm happy to report, has matured and grown in wisdom and consideration for others. Let's not, then, continue to appeal so lopsidedly to the selfish in our public audience. Let's not sit, like a piano player, with one hand tied behind his back, beating monotonously on the bass to the base in mankind.

Putting this all another way, and at the hazard of your misunderstanding me, we've been doing only *half* of our job. We've been talking and writing entirely too much about our standard of living and not thinking nearly enough about our very real problem of dying! As a great minister recently said, "We have been 'majoring in the minors.'!" We're playing chiefly one end, and the bass end at that, of our human relations piano!

Quickly to sum up, I feel "We're Working While Rome Burns." Not all of us in business and the professions, but far too many, are so engrossed with the challenge and thrill of doing things, making things, and selling things that we fail to realize how close, how widespread, and hot is the fire of slavery.

Second, I fear that much, far too much, of our story, "the story of business enterprise," is slanted to appeal chiefly to the selfish, the material side, of our listeners. I know the importance of television sets, bathtubs, and automobiles. Nonetheless, if we are honest with ourselves, we know that it is not for such things that men will die. But men will die for things so deep within themselves that they cannot even put them in words. And those are the things that will win this fight, if only we can make Americans realize that it is these deep things that are at stake.

Add them up, and they come down to the concept of human freedom, the freedom of the individual. It is the noblest concept by which any government has ever sought to rule. This concept of freedom can stir men's minds, can rouse them to topnotch fervor.

Why don't we start playing our American story now on every key of *both* our rational and emotional pianos?

Why don't we play our great American symphony with emphasis now on the high treble of nobility and statesmanship?

Finally, let's do this, not for ourselves, but for our children here and for all mankind over there, especially for those sad people who, through their complacency, have lost the freedom which we still. . .thank God. . . have here.

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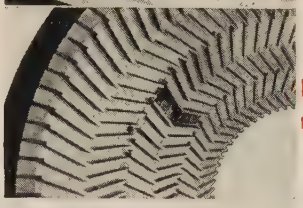

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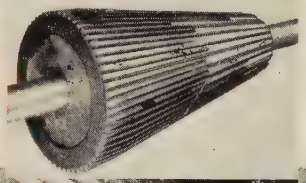

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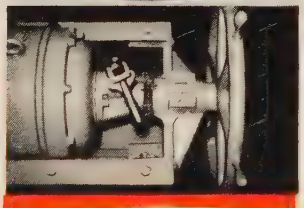

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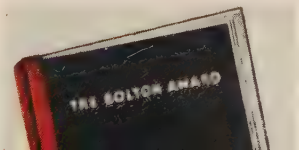
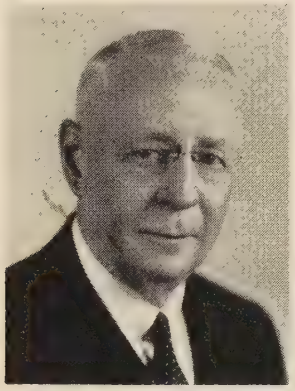


INDUSTRIAL PROGRESS OF THE FUTURE—A CHALLENGE TO TOP MANAGEMENT

H. W. PRENTIS, JR.



H. W. Prentis, Jr.

In approaching the subject of my address "Industrial Progress of the Future—A Challenge to Top Management," let me say at the outset, that the manager is the dynamic, life-giving element in every business. Without his leadership the resources of production remain resources and never become production. In a competitive economy above all, the quality and performance of the managers determine the success of any business enterprise. For whether a business goes ahead or falls back in the competitive race is decided by the quality of its management brains at all levels of its organization.

Management is also a distinct and leading group in any industrial society. On its performance ultimately depends the standard of living of a nation as well as the strength of its social beliefs, its social cohesion, and its ability to withstand the poison of totalitarianism.

What do we mean by "manager?" What distinguishes a manager from the businessman as the economists see him on the one hand, and from the administrator in government, the armed forces, or the church on the other? A manager deals with economic resources. He aims at economic performance and is measured by economic results. That distinguishes him from the administrator in any nonbusiness institution.

The businessman of the economists behaves purely in adaptation to economic forces which he neither creates nor controls. His behavior is defined in the economist's concept of "maximization of profits," his procedure and conduct being aimed at making the best of whatever his environment and the physical forces in it can produce.

By contrast a manager manages. His attitude is like Napoleon's who asserted: "Circumstances—I create circumstances." In other words to be a manager implies the responsibility for attempting to master the economic environment—and the social environment too; for planning, initiating, and carrying through changes in economic conditions; for constantly pushing back the limitations of economic circumstances on the enterprise's freedom of action and on the economy's standard of living. What is possible is only one part of a manager's job. What is desirable in the interest of the enterprise and society in general is the other part.

H. W. Prentis, Jr., Chairman of the Board, Armstrong Cork Co., Lancaster, Pa.; Past-President, National Association of Manufacturers, U.S.A.

And while man can never completely master his environment, while he is always held within a tight vise of possibilities, it is management's specific function always to make what is desirable, first a possibility and then a reality. Management is not just a creature of the economy; it is partly the creator of the economy as well. And only to the extent to which it masters economic circumstances and changes them by conscious, directed action, is it really doing its job.

Today management is confronted with tremendous technological change—a change which creates outstanding opportunities for constructive and productive management action all over the world. But it is also a situation which presents management with grave new responsibilities, a change which makes unprecedented demands on its competence, its knowledge, its performance, and its sense of responsibility. This new technology is not in the future; it is already upon us. It is not merely a matter of gadgets or of machines. It is a new principle of production, an intellectual, even a philosophical concept—and that of course gives it its impact, its importance, and its penetrating power.

Here, in the United States, the coming of this new technology has provoked a veritable deluge of moonstruck stargazing, a torrent of pseudo-scientific fiction. Dreams of the "push-button" factory abound in which robots turn out mountains of goods effortlessly while human beings by the millions find themselves in enforced idleness. The new technology, we are being told, will require giant business to grow even bigger while squeezing out the small and independent enterprise. It will require allegedly such capital investments as only government can supply. It will force us, it is asserted, into the planner's paradise: an economy in which government collects, controls, and directs all the capital accumulations of the nation. At the same time, we are being told, the new technology will make management unnecessary. All it will need are technicians.

I am sure all of us here remember that this prophecy of doom was the stock in trade of left-wing propaganda 20 years ago. Every item in this prediction was then urged upon us in the name of human welfare. Now, that the left-wing doctors have become discredited by two decades of experimentation with their nostrums; now that we no longer can be coaxed and cajoled into swallowing their theories under the pretext that they will make us healthy and free, the pseudo-scientific fiction about the new technology tries to frighten us into the same kind of nightmare.

I do not know how much of this stargazing is going on in other countries, but I do know that there is no truth in it. Indeed we do not have to theorize about

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the meaning of the new technological changes. We can see and inspect them at work in hundreds of plants and factories now functioning. We already have industrial enterprises that show clearly what the new technology means. And whenever you actually look at it instead of theorizing about it, you find that its reality is the exact opposite of the horror stories—with their robots, their bigness gone mad, their technology become man's master rather than his servant.

And we in management must clearly realize these facts. Our capability to manage successfully will increasingly depend on our understanding of the tools of the new technology and on our ability to use them right. The social and political future of our free society demands that we oppose to these fanciful speculations of technological horror the sober but also encouraging truth.

Let me say first that the popular belief that the new technology will replace human labor by robots is utterly false. On the contrary, it will employ more people and above all, much more highly skilled and more highly trained people. It is no longer generally believed, as it was a scant 20 years ago, that mass-production methods—yesterday's technological change—throw people out of work. Wherever such procedures have been introduced, we all know they have rapidly increased the number of job opportunities in industry. For every livery stable, for example, that the automobile drove out of business, there are today half a dozen or more gas stations, automobile dealers, and automobile repair shops—owned locally and independently and providing a better living to many more people than the livery stable ever afforded.

But it is still widely believed that mass production replaces skilled labor by unskilled labor. We know this too to be a total fallacy. Here in the United States where mass production methods have been applied on the broadest scale thus far, the one class of employees that has been growing most rapidly in numbers and proportion are skilled and trained people. And the truly unskilled laborer of yesterday who contributed only his brawn has become the semiskilled machine operator of today—a man of higher skill and education, producing more wealth, and enjoying a vastly higher standard of living, than he ever did before.

The technological changes now occurring will carry the same process a few steps further but they will not make human labor superfluous. On the contrary, they will require tremendous numbers of highly skilled and highly trained men—to design the new tools, to produce them, to maintain them, to direct them. Indeed the major obstacle to the rapid spread of these changes will almost certainly be the lack in every country of enough workers possessing sufficient skill and training.

It is similarly not true that the new technology demands the giant enterprise, let alone that it will squeeze out the small, independent producer. In some industries it may well increase the size of the most economical unit. In others—one example is likely to be the production of raw steel—it is likely to make significantly smaller units economically possible, if not desirable. More important: the new technology requires much greater delegation of decision-making authority to the management of small units than was needed under former conditions. An enterprise in which all decisions were centralized at the top would become unable to live and to survive.

It is also not true that the new technology brings a tremendous increase in capital requirements. Investment per production worker will of course rise. But there is nothing in our experience to make it appear likely, let alone certain, that investment in terms of constant value per unit of output will significantly increase.

Above all, however, the new technology will not render managers superfluous, will not convert them into mere technicians. On the contrary, it will make tremendous demands on management, on its competence, its vision, its economic knowledge and skill, its ability to make rapid decisions, its flexibility—in short—its ability to manage. So vital are these requirements that they will make it absolutely impossible to operate the new technology and to derive its benefits under any form of centralized planning from the top. On the contrary it will be even more important than it is today that management decisions be made as far down as possible in the organization. Hence it will be even more essential that management at the bottom of an enterprise be as capable and as competent as it is in the middle or at the top levels. Any society that were to attempt to get rid of the free management of autonomous enterprise, and to run the economy by centralized governmental planning in the era of the new technology would perish miserably, as did the great reptiles of the Saurian age whose small and completely centralized nervous system proved unable to adapt itself to a changed environment.

What then concretely are those new demands that technological changes are about to make on management—its vision, knowledge, skill, and competence? They are eight in number:

1. First, the new technology requires that management learn to understand fully what is involved, and add a new dimension to its competence and to its vision.

2. The new principles of production demand, secondly, that management create markets. It can no longer be satisfied with the market as it exists. It can no longer see in selling merely an attempt to find a purchaser for whatever it is that the business produces. It must create customers and markets by conscious and systematic work. It must focus its effort continuously and sedulously on creating mass-purchasing power. To that end it must constantly work on the long-range job of changing consumers' habits and of educating them to an understanding of the new opportunities rising incomes and advancing technology open up for a higher standard of living.

3. In the third place, the new technology requires a tremendous increase in the number of trained and educated people in business—an increase of almost astronomical proportions. For the new method consists in augmenting man's control over his economic environment by multiplying his mind power—whereas in the past we have attempted to multiply first his physical strength and then his skill. Management has a tremendous responsibility in finding people of the proper ability—no matter what their birth, religion, racial origin, or formal education; in giving them the vision they need; and in conveying to them the knowledge, the skills, and the understanding they require. In

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every society we have any knowledge of, in the past, the economy could afford only a very small number of educated people. The great bulk of humanity always had to work with their hands lest society starve. Under today's industrial conditions, for the first time the opposite is the case: our real problem is that we cannot afford large masses of uneducated people; that the more educated, the more conceptually trained, the more managerial people we possess, the stronger we become.

4. In the fourth place, we must never forget that this also creates a tremendous problem in the managing of people. Indeed our methods of management by command have already become obsolete. The highly trained, highly educated employees we need in the business of today and tomorrow, people who will have to work by using their own judgment and their own knowledge, cannot be ordered about. They must be led to give their best voluntarily. They must be managed by objectives and measurements, by persuasion and leadership. Thus the new technology involves new competence, new skill, and a new basic understanding in the management of working people.

5. Fifth, in the interest of the business as well as in that of society, we will have to learn to make employment as stable as possible. I am here, let me emphasize, not referring to the guaranteed annual wage some of our union leaders are talking about. The attempt to guarantee security of employment is as futile as an effort to insure immortality. It can only end in bitter disillusionment. And in the process of attempting it we would tend to paralyze our economy. But the interests of the individual business enterprise themselves, as well as those of society, demand that we go as far as is economically sound in the direction of stabilizing employment. To get rid of large masses of people under the new technology when economic conditions change for the worse, will be very expensive for business. Far too many of its people possess singular skills and knowledge which, once lost, are not easily replaced. At the same time society today demands that the employee be given the optimum of income and employment stability.

6. Sixth, the new technology imposes upon management decisions for an even longer future than the one for which we have to make plans and decisions now. Hence management obviously needs much better tools to make long-range decisions than we now possess; tools of economic analysis which go far beyond the attempt to read the business cycle to which so many managers and economists confine themselves today.

One tool which in my own company has proved effective over a quarter-century now is "management by objectives" under which for every major product line 5-year sales goals are set at frequent intervals. These objectives then determine what capital investments we shall have to anticipate making; what profit margins we should seek; how much we should spend for research and development, for marketing organization, sales promotion and advertising; how many management people we shall need—where and with what qualifications. These objectives are of course only a compass bearing. They have to be re-examined frequently. They have to be adjusted to economic disturbances or to product developments that come out of the laboratory or result from our competitors' efforts. But the setting of these objectives helps us to manage. They enable us to decide where we should be at any given time in the future, and to find out what we must do to get there. They finally enable us to measure our progress and achievements, to see whether we are growing or standing still, advancing or sliding back.

7. In the seventh place, the need for long-range decisions also means that manager development becomes vital in every business. For only the deliberate training of managers who can rectify the positions management takes today can convert long-range decisions for an uncertain and always unknowable future into rational and successful ones for tomorrow. Also, the demands on executives are increasing so fast that we have to make sure that the competence and performance of our managers grow with them. In short, management development which does not just consist of picking out a few "crown princes" to replace today's top managers but which works systematically and consciously at the improvement of performance and ability of the entire manager group, is a vital necessity under modern industrial conditions.

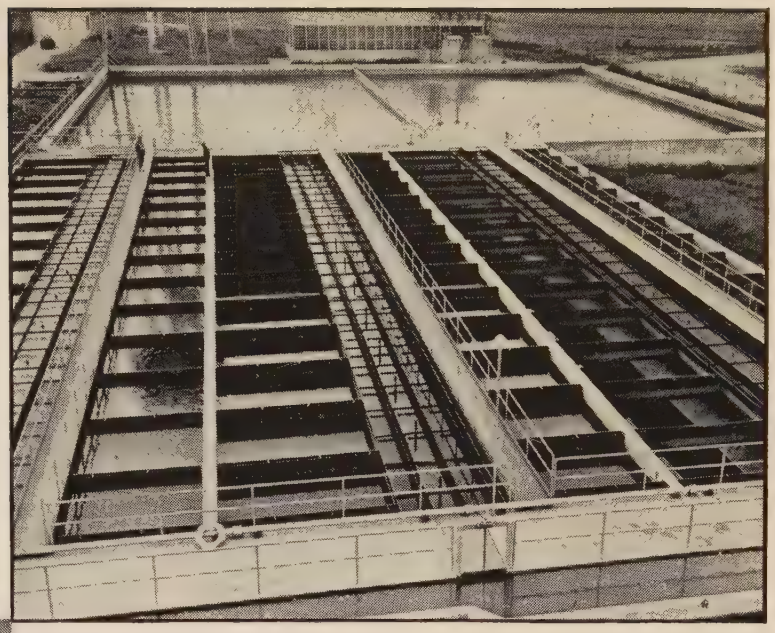
8. Finally, we have to learn to apply much more thoroughly and much more consistently the science of management. We have learned, during the last 50 years, a tremendous amount about managing. While it may never be an exact science, it certainly has acquired the status of a true profession. Obviously the more we apply its principles and concepts to the actual job of running a business enterprise the better we will manage. Here lies one of the biggest areas for the improvement of management performance.

But the new technology also makes heightened demands on the social responsibility of management. It requires in particular that we so manage as to root our decisions and the actions of the enterprises we are responsible for in:

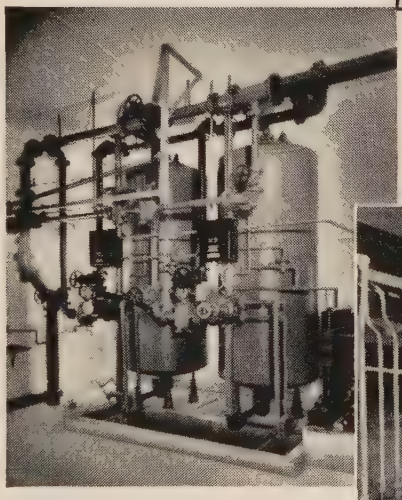
The principles of liberty, not the principles of compulsion;
The principles of reason, not the principles of force;
The principles of leadership by objective goals and by integration of voluntary efforts into cooperative teamwork, rather than leadership by command or fear;
The principles of morality, not the principles of materialism;
The principles of religion, not the principles of atheism;
And finally that management and the business enterprise be rooted in the deep belief that however complex society and its social relationships may become, the natural rights of the individual as a person, including the right to acquire and hold property, are of a different order of priority than the rights of society.

Perhaps you are surprised that a hard-headed businessman like myself should define management in terms of morality. Perhaps—I trust not—you may say to yourself that these are the things one is expected to say in a speech, but they can be forgotten when one returns to his daily work. Let me therefore stress that it is precisely because I am a hard-headed businessman that I lay the foundations of management on moral values. My working life has paralleled the great industrial revolution in the United States; it has paralleled the growth of my own company. Looking back on this past half century, I see above all that it is the moral values, the moral foundations, that are hard-headed and practical. Leadership on any other basis misleads and ruins. If it be sentimental, sentiment, as in the case of Hitler, always turns into bestiality and oppression. If it be expedient, expediency, as Mussolini's example, always results in ultimate failure.

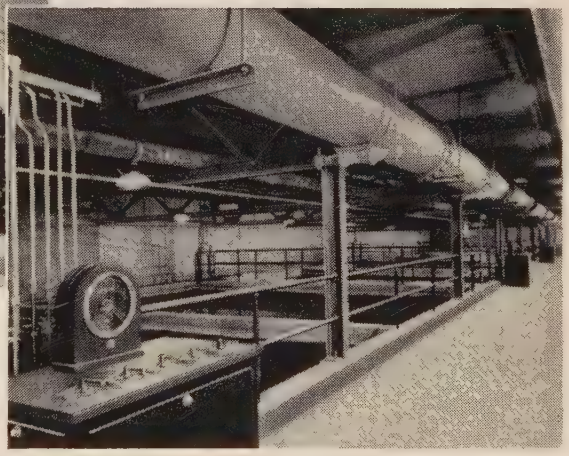
Which process will solve your quality-control problem?



PRECIPITATOR clarifies and softens cold water. Reduces turbidity, color, iron and manganese . . . banishing stains, off-shades, dull products.



ZEOLITE SOFTENERS (Ion Exchange) quickly remove hardness . . . prevent troublesome scale in bleach tanks, boilers. Reduce staining iron, manganese.



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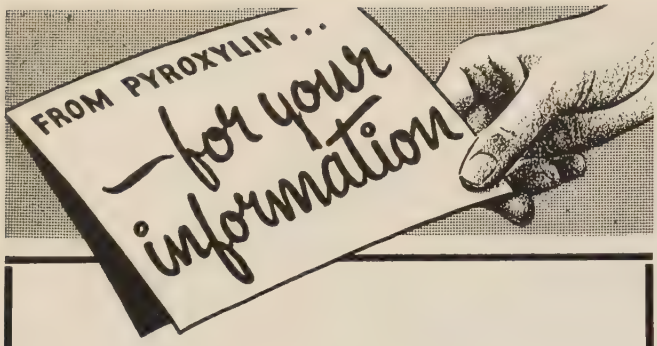

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PAOLI PENNA.

I would be the last person to pretend that we here in the United States know all the answers. I am only too well aware of the tremendous problems of an industrial society—many of which we have yet to tackle. I am only too conscious of the mistakes we have made and are making—mistakes for which the generations that will follow us will have to pay a heavy price. But one thing we *have* learned in these 50 years of growth and development; namely, that management, precisely because it is responsible leadership, must be moral in its fundamental principles.

I stress this above all because I see such tremendous opportunities for management under present-day conditions. In Western Europe, for example, the cradle of modern industry, I see a new stirring under the scars and ruins left by war and oppression. A new young generation of managers seems to be emerging, eager to do new things, tired of the false security of state control, subsidies, and regimented markets, determined to prove wrong the lugubrious prophets of Europe's doom.

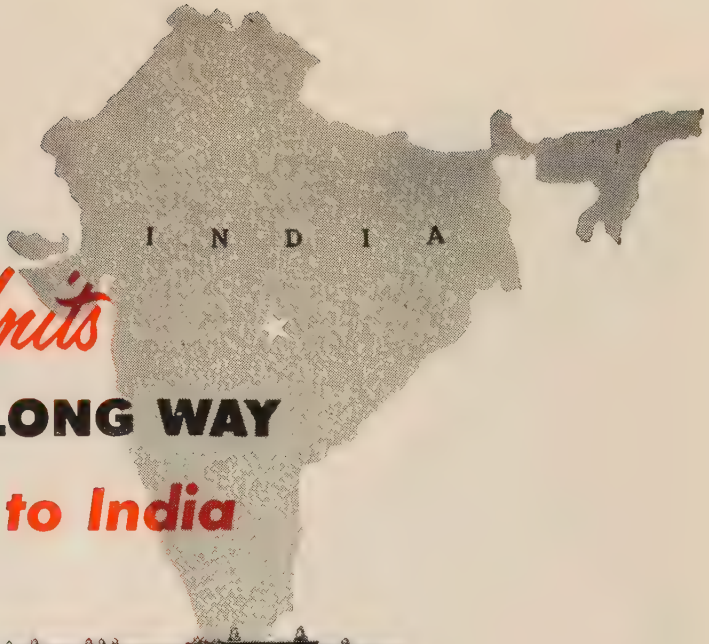
The new technology will give strength to these forces at work throughout the Free World. It will help to bring nearer the international unity of free peoples, a unity of purpose, belief and direction, based on diversity of tradition and culture, on mutual interest and on mutual respect. It will help to make stronger new countries seeking to develop new industries or old countries striving to recover the leadership, courage, and vision that were theirs of old.

But the new technology will prove beneficial to the peoples of the Free World only if we in management use it right. It requires more than ever that we, in managing, root our decisions and actions on the bedrock of moral principles, that we lead not only through competence and skill, but through vision and responsibility.

"Scientific management" began 60 years ago, as a study of individual motions in the performance of specific jobs. For many people "scientific management" is still a specialized discipline concerned with technical skills. However, we have gone far beyond the work of the pioneers, even though we have built on their foundation. Scientific management today is the systematic organization of economic resources for economic and social betterment. It is the carefully planned and organized leadership of people to multiply their efforts for the common good. The challenge which the industrial progress of the future poses to top management is above all else to apply in practice what we have learned in 60 years of "scientific management."

It is also a challenge to us to make of management a bond of unity. In this age of nationalist passions, we sorely need common ties transcending the barriers of language, class, race, and custom. One such bond, the greatest, is religion. Another one is science with its international language and its universal method. A third one should be management with its common problems, its common work, its universal responsibilities. The extent to which we make management a bond of unity, internally as well as internationally, will be the test of our claim to leadership in today's industrial society.

Presented at the Ninth Engineering Conference of the Technical Association of the Pulp and Paper Industry, Philadelphia, Pa., Oct. 20, 1954.



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Now on order for National Newsprint & Paper Mills, Ltd., of Chandni, Central Provinces, India, is a B&W Recovery Unit designed to burn 10,825 lb of black liquor per hour and to deliver 19,800 lb of steam per hour at a design pressure of 200 psi and 378 F. Ebasco Services Incorporated is supervising the installation and operation of this plant.

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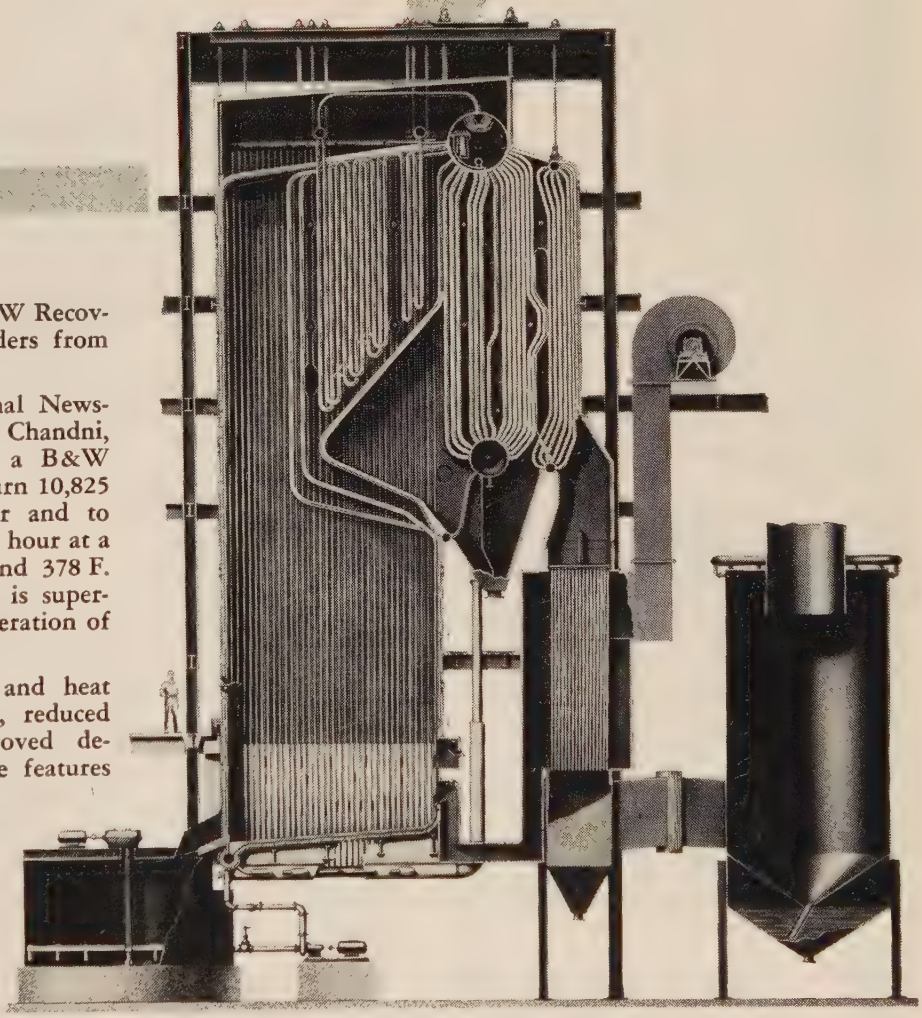

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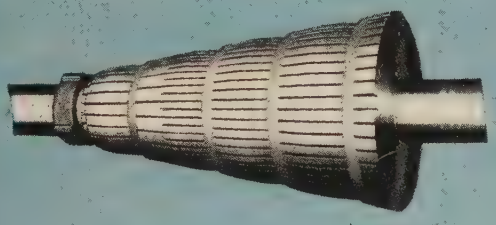

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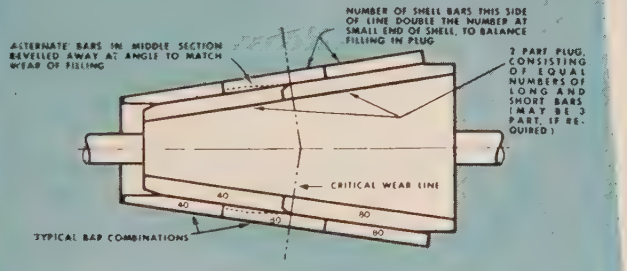
NUMBER OF SHELL BARS THIS SIDE OF LINE DOUBLE THE NUMBER AT SMALL END OF SHELL, TO BALANCE FILLING IN PLUG
ALTERNATE BARS IN MIDDLE SECTION BEVELLED AWAY AT ANGLE TO MATCH WEAR OF FILLING
2 PART PLUG, CONSISTING OF EQUAL NUMBERS OF LONG AND SHORT BARS (MAY BE 3 PART, IF REQUIRED)
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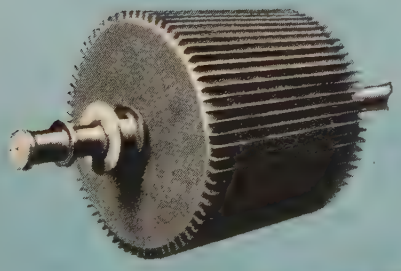

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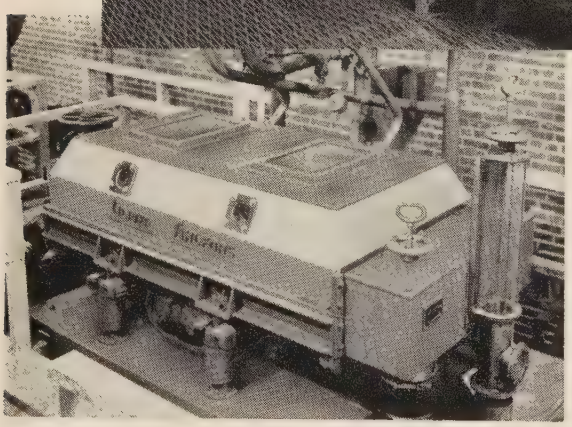

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Oliver Board Former
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Sweetland and Kelly Pressure Filters

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Oliver-Ahlfors Upflow Pulp Screen

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Oliver Vacuum Pump
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Olivite Acid Handling Pump
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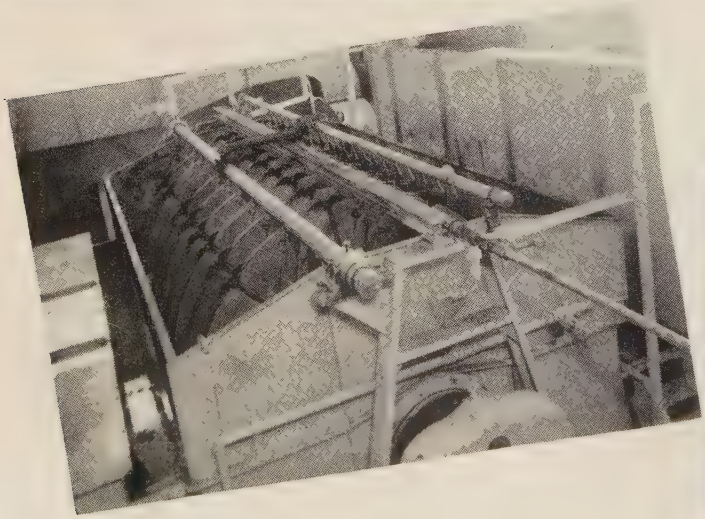
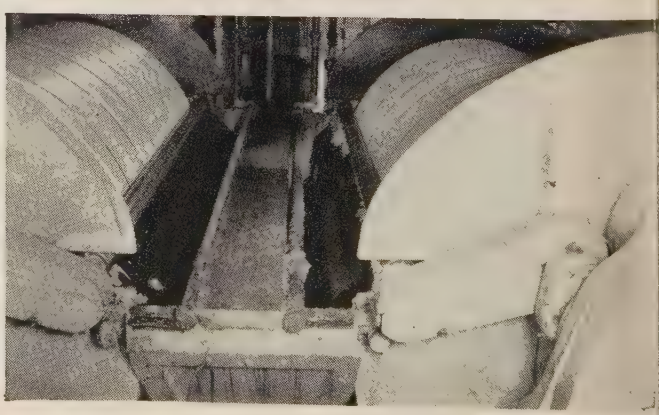
Oliver Centrifugal Pump—(Stainless Steel)





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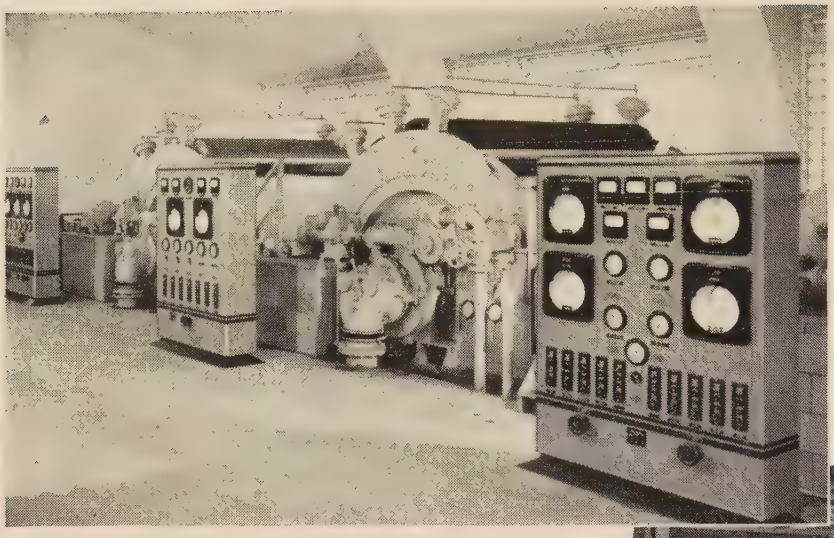
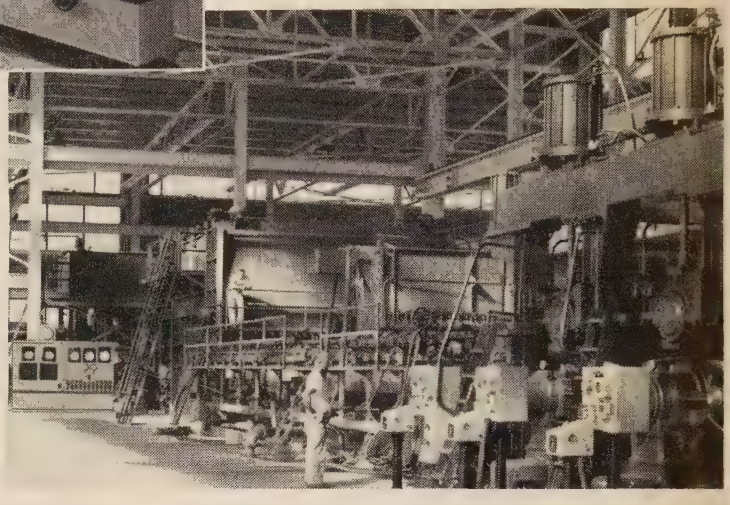


◀ *pH control in your bleach plant will improve quality and save chemicals.*

pH control on your paper machine will improve and maintain quality and permit higher machine speeds. ▼



Better Mill operation... Better finished product...

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Wherever pH is an important factor in your process, automatic measurement or control by Foxboro instrumentation can bring big improvements in results. It means brighter pulp in bleaching with minimum chemical usage . . . better quality paper at higher machine speeds . . . more reliable machine operation . . . or any of a number of other advantages.

BASED ON DYNALOG ELECTRONIC INSTRUMENTS

Designed with the Foxboro Dynalog* as the basic instrument, Foxboro pH systems take full advantage of the greater sensitivity and reliability of electronic circuits. The Dynalog provides flawless, *stepless,* continuous measurement or control through use of a simple variable capacitor. It has no slidewire, no batteries to standardize, no high-speed motor, gears or galvanometer. Maintenance is eliminated, except for occasional replacement of standard radio tubes. Available in recording or recording-controlling models.

Beckman glass electrodes are the primary measuring elements of Dynalog pH systems. They are suitable for use in nearly all types of liquids, regardless of color, viscosity, rate of flow, suspended solids, oxidizing or reducing agents.

WRITE FOR COMPLETE INFORMATION

Whatever your requirements, there is a Foxboro Dynalog pH System to meet them. Consult your nearest Foxboro representative — or write for Bulletin 430. **The Foxboro Company, 7811 Neponset Ave., Foxboro, Mass., U.S.A.** Branch offices in principal cities.

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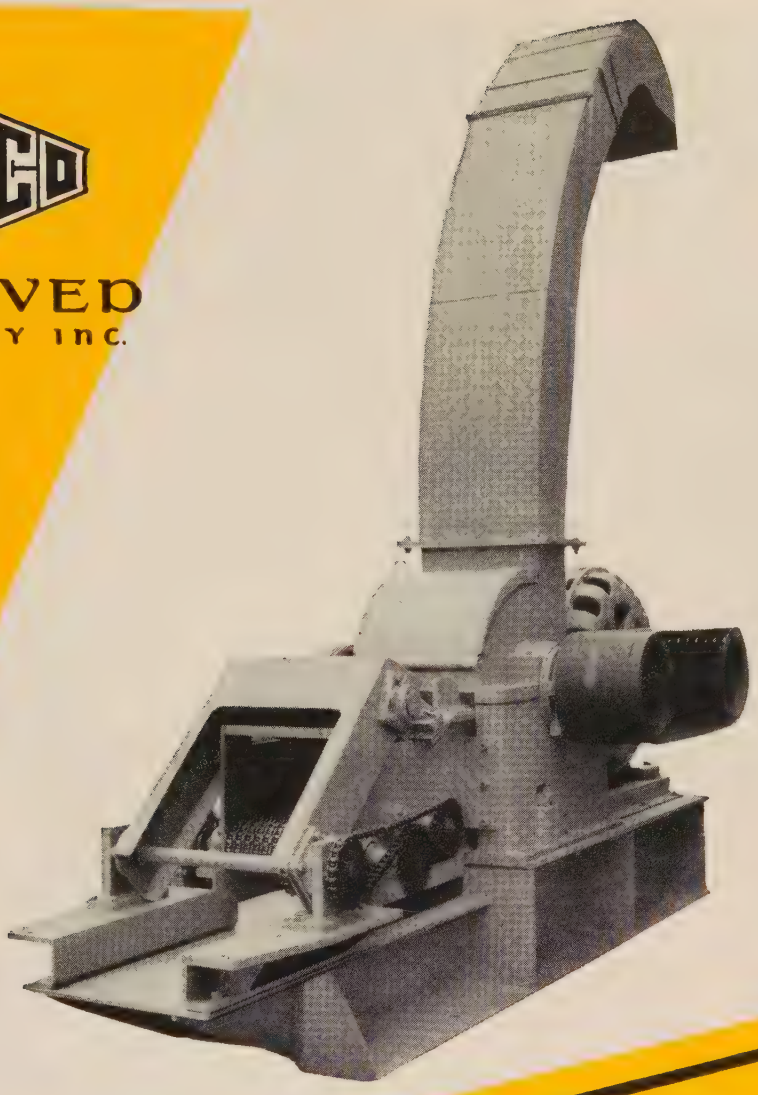

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. . . "perhaps the first of its kind to invade the high quality pulp chip field" . . . (American Pulpwood Association release, #201).

For the quality processing of your sawmill residues and logging slash, we offer this rotary cutter head type chipper.

Its horizontal power feed permits the handling of material of any length in single floor installations.

One of these units will economically handle all the chippable residue of any sawmill up to the 150M-F.B.M. per day class.

Ten inch diameter whole logs and sixteen inch width slabs are readily handled.

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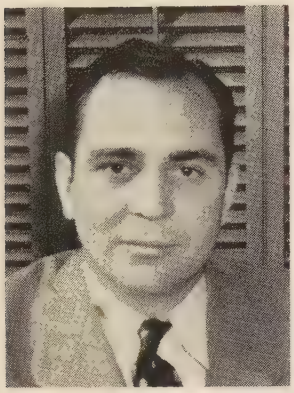
A LAYMAN LOOKS AT TAPPI

J. W. WARNER



J. W. Warner

In appearing before this distinguished group, I am reminded somewhat of a character, Sam Swink, from the late Judge Samuel Baldwin's immortal classic "Flush Times" in Alabama and Mississippi with which many of you are familiar. For the benefit of you who are not, however, "Flush Times" is a history of the Legal Bar in West Alabama and East Mississippi during the halcyon period of 1837–41. It seems that in those days whenever a man failed in any kind of business he invariably applied to the Judge of the Circuit Court in his area for a license to practice law, which the Judge usually granted after going through the preliminary of asking a few perfunctory questions. Well, Sam was a cross-roads grocery man who had failed in business, so he appeared before the Court to stand an examination to become a licensed member of the legal profession. One of the questions asked Sam was: Whose child is an illegitimate child? Well, then as now, as most of you know, an illegitimate child belongs to the mother; the father has no rights at all.

Sam's reply was: "Judge, I ain't never seen nothing like that in no law book, but I have generally noticed that it belongs to the young man in the community most able to pay for its upkeep."

Sam's approach to the problem was that, not of a member of the profession, but of a layman, a practical or everyday approach, if you please.

In talking to members of TAPPI, my remarks must of necessity be like Sam Swink's, those of a layman.

If a member of any profession is to offer wise counsel, he must know the reasons behind his every move: particularly is this true of the chemical profession. It has often been said that a doctor buries his mistakes. A technical man's mistakes, however, are not so easily disposed of. They remain for years as an ever-present reminder not only to the man himself, but to the members of his profession, and above all, to the people he is, or should be, trying to reach, the operations people and management, in whose hands is the major portion of the production of paper.

There is a little quatrain by Rudyard Kipling that I like to think of as being applicable to most any subject or situation, and it is upon part of these lines that I am going to base my remarks this noon. They are:

> I have six honest serving-men
> (They taught me all I knew)
> Their names are What and Why and When
> And How and Where and Who."

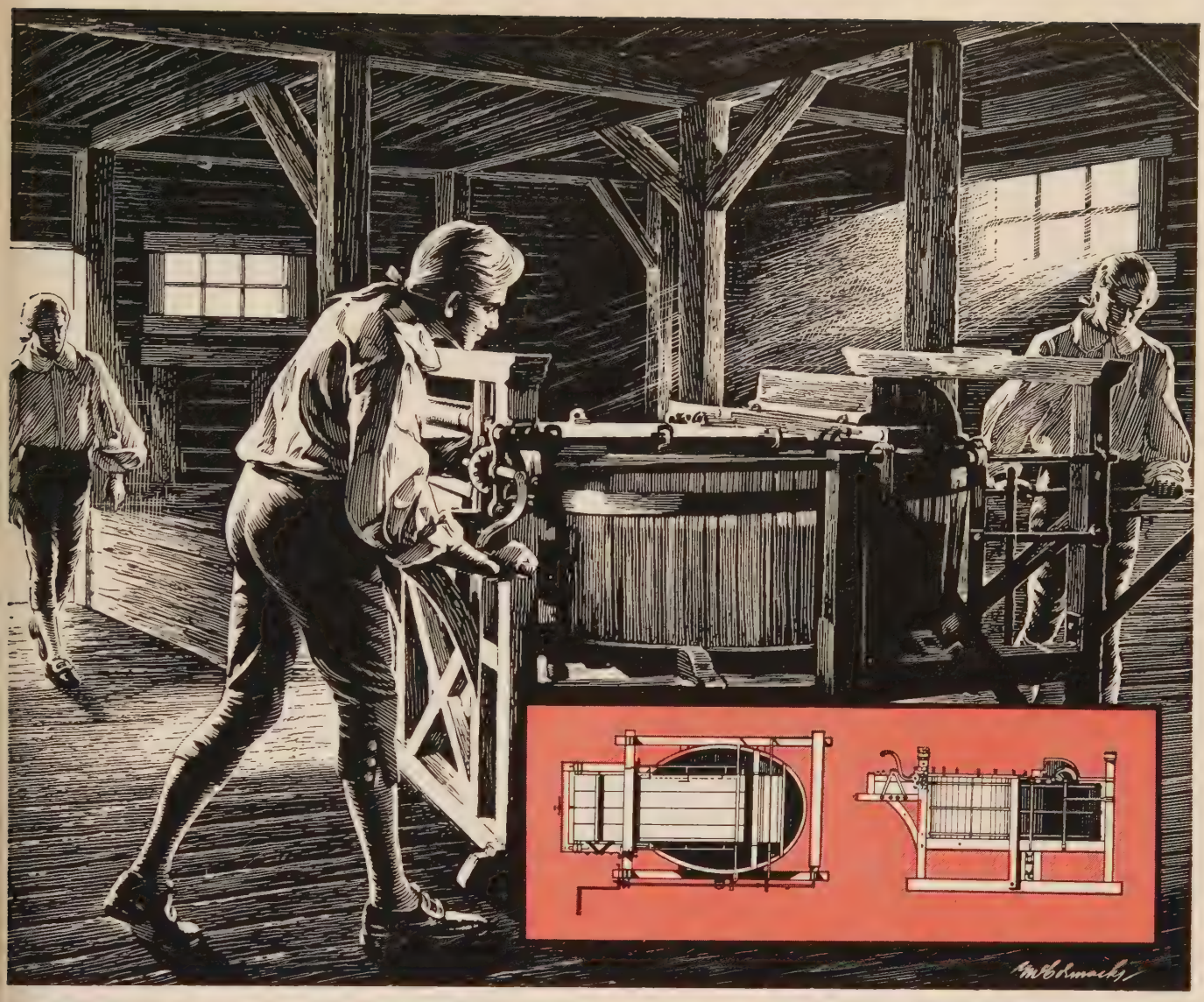
You will note that Kipling's first honest serving-man's name is WHAT. The first question that naturally arises, therefore, is what chemistry? Webster defines chemistry as: the science that treats of the composition of substances and of the transformation they undergo. We here today, however, are primarily concerned with alkaline pulping. I do not know the definition you members of TAPPI have for alkaline pulping. To me, a layman, alkaline pulping, simply put, is the use of chemistry and chemical engineering to separate the socially and economically useful components of a tree from those components for which no beneficial use has been developed.

The socially and economically useful part of the definition I can understand. This sulphate industry has not made its tremendous growth since the 1930's because someone wanted to build a plant. It will not continue to grow or even stay where it is, unless it continues to supply desired and useful products. The man with a dollar to spend does not concern himself with creating opportunities or jobs for others. He is only interested in getting the most of his desires for that dollar. The number of people employed, the vast forest program, the tremendous investment in plant, or the fact that the paper industry is the 5th largest have no influence on him whatever. He is not a philanthropist, when purchasing his needs. Under the American system we must not only merit but earn our position in society. Our technical advances must recognize this proposition, and it is largely through them that we maintain our position. Any way you stack the What of our definitions, it must come out as a more useful and better service to human welfare.

Right here I would like to digress for just a moment, and offer what I think and hope you will take to be a word of constructive criticism to the members of this profession.

I believe myself to be a person of average intelligence and education. There have been times, however, when in discussing technical problems with various members of the profession, that it would not have been difficult for me to follow them a lot quicker or faster had they expressed themselves in less technical and scientific terms, or technical twist of mind, if you please. There are many people working in the industry who have no technical background, or technical perspective. All of the nontechnical people must understand what you people are trying to do or say. It is my candid opinion that many of the nontechnical people could not have understood them at all, had they couched their talk with them in the same language they used in talking with me. It has been my observation that the

J. W. Warner, Executive Vice-President, Gulf States Paper Co., Tuscaloosa, Ala.



Papermaking Went Into High Gear With This Machine in 1798...

An important event in the history of papermaking was Nicholas-Louis Robert's invention of the paper machine over a century and a half ago. No longer would the slow methods of forming paper by hand limit size and quantity of paper sheets. Robert's machine formed paper of continuous length upon an endless woven-wire cloth which retained the matted fibers. Today more complex machines, operating on the same principle, produce a tremendous volume of paper. Helping maintain its quality are high-grade raw materials produced by A. E. Staley Manufacturing Company, supplier to leading mills for more than 30 years. Discover the many advantages Staley can offer *you*. See your supplier or write for details today.

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practice of being technical is not peculiar to this profession, but is common to all professions. Under the American system all members of the team must understand the signals if we are to be a success.

In this connection, I am reminded of the story that is told about Charles F. Kettering. It seems that not long after Kettering invented the automobile self-starter in 1910, he attended a convention of electrical engineers. One of them walked up to him and indignantly blurted out: Mr. Kettering, you have violated the fundamental principles of electricity. Mr. Kettering smiled and replied: "I didn't violate the principles of electricity. I just invented the self-starter."

Once again, I say I hope that you will take this criticism from a layman in the spirit in which it is intended.

Now, let's talk a little about Kipling's second honest serving man, WHY.

Why technical men in industry: honest serving-man no. 2, if you please.

All of you have heard the expression: He recovered in spite of the doctors. Some of you may not agree, but I believe the industry would not have grown as it has without chemists.

My grandfather established a bag factory at the old Orange, Tex., mill in 1912. Later, he built a kraft mill at Braithwaite, La., in 1915. The product in those days was known as nigger kraft. It often contained so much kerosene that the paste would not hold the bags. Nobody wanted it. We hired a consulting chemist for help. From this beginning we acquired our own chemists.

A doctor or a lawyer does not locate in a community where there is no sickness or litigation; where there is no need for his services. A business does not add to its staff for fun. Today, there are many technical people in the industry. The growth of your organization reflects their increase.

Why? I say that it is for two reasons:

1. They came because there was both an opportunity and a need for them.

2. They remain because the development of the industry they helped bring about increased the demand for their services.

Much has been done in the industry and much more remains to be done. That which we do not know greatly exceeds that which we do know. Our forests are our only renewable natural resource. Foresters have and are making great strides in improving this resource. Utilization must keep pace with and aid in improving this forest resource. We need better utilization of the tree. Not only the parts not now too desirable for pulping, but the parts now used as fuel. Waste wood species now crowding the pines must be utilized. The technical professions in the industry must work together now to give us a more economical and far-sighted utilization of our forest resources. If we work wisely we can pass on to the future generation a greater resource than was passed to us. This is not true of other resources.

WHEN—technical coordination?

The time is now. We have too long pushed our progress by point of interest. It isn't enough to have a good program, good technical design, or a good operation. We are a forest industry. Our program must be coordinated operation that makes for the best and most complete utilization of the natural resources God has and is giving us.

Honest serving man no. 4—HOW?

Throughout this talk I have entertained the hope that you would bear in mind that my remarks are those of a layman, an ordinary citizen, if you please. I have tried to tell you how chemistry is looked at through the eyes of the ordinary citizen, Joe Blake or Jim Jones. I would not now be so presumptuous as to attempt to tell you, how. Still speaking as a layman, however, I cannot forego the opportunity to caution you to practice your profession in a language that the so-called man in the street can understand. To accomplish that for which you are striving, you must be understood. In my contacts with technical people, I frequently have the feeling that they are prone to consider technical work an end in itself, as a motive in itself. The aim of any business is to make a desired product, to make it efficiently in order that it may be sold at a profit for the stockholder. A laborer must be worthy of his hire; capitol is entitled to a fair return on its investment. Technical action that contributes toward these ends is useful; technical action that does not lead in this direction is at best rather academic. It may, in fact, even thwart the purpose for which the technical personnel were employed.

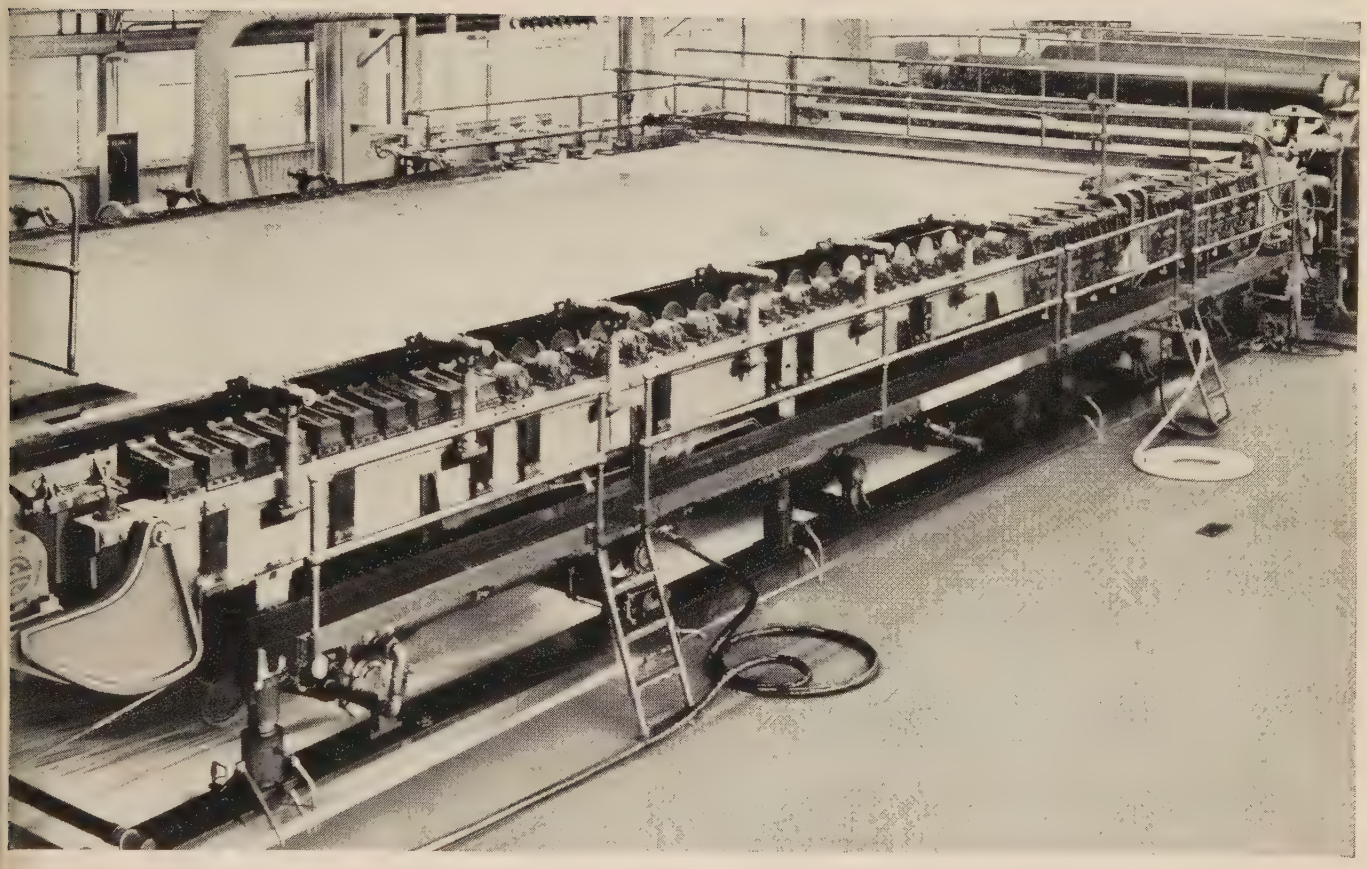
And now for honest serving-man no. 5—WHERE chemistry?

The answer to that question is quite obvious—in all its phases and wherever the interests of mankind can be best served. You and I, however, are primarily concerned with chemistry in the pulp and paper industry. It is my considered judgment as I have previously stated, that the most fertile field, the field that offers the greatest opportunity, a field that will challenge, not only your technical knowledge but your patience as well, the field in which you can best play your part in conservation of our God-given natural resources, is the field of wood utilization.

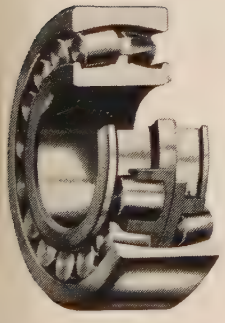
WHO chemistry—Honest serving-man no. 6. Your selfish interest and my selfish interest answers that question with one word, TAPPI. Selfishness has never been a characteristic of the scientist, however. Had it been, the world would not today know the standard of living that the countries operating under the free enterprise system enjoy. I would urge you, therefore, to be continually diligent in the future, as you have been in the past, in search of new, better, and more economical methods of accomplishing that for which you are striving.

The goal for all of us is achievement and accomplishment. TAPPI has made great strides in the field of pulp and paper chemistry. Distant horizons, however, beckon the chemist ever onward as they did the pioneers in days gone by. To attain the What, Why, Where, and Who of chemistry is going to require more than laboratory chemistry. It is going to require thoughtful planning by management and as a source of supply for executives, chemistry can be of great service to the wood-using industries of the world. The most serious shortage American business faces today, according to *News Week* is not a shortage of certain basic raw materials or trained technical men, but a shortage of management talent. I was interested in an article in the same issue of *News Week* titled—What I Look for

TORRINGTON SPHERICAL ROLLER BEARINGS' load capacity and self-alignment feature keep this Bagley & Sewall high speed Fourdrinier wet end operating smoothly and efficiently despite vibration and the long support between bearings.



For longer life...at lower cost



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in Picking an Executive. Donald Douglas, president of the Douglas Aircraft Co., said, and I quote: "Technical competence is only one essential for executives. Personally, I seek a warm, balanced human being. Good executives, and I would add good chemists, must have judgment, self confidence, a sense of justice tempered with kindness, a sense of fair play, an instinct for team work, and a talent for helping and teaching their associates." Thomas J. Watson, Board Chairman of the International Business Machines Corp., has this to say on the subject of picking good men: "Nobody can develop a good man. What I have done is to give my men an opportunity to develop themselves. That's why I have always picked men with individuality, imagination, and the courage to make mistakes." Next, I quote Ben Moreel, Jones & Laughlin Steel Corp. board chairman, on the subject. Here's what he has to say: "The *distinguishing* characteristics of a successful top man are more qualitative than quantitative. We are looking for qualities covered by the five I's: intelligence, imagination, interest, integrity, and initiative."

And finally I quote: The day is passing when a man can get ahead by just knowing gimmicks and gadgets. The new type of industrial leader must know what's going on in the world, know how it's going to affect his business. He has a broad view, not confined to merely one specialty.

TAPPI has in the past furnished, and is now furnishing many, probably more than its share, of good executive timber; men who possess the qualifications outlined above. The pulp and paper industry looks to TAPPI for even *more* of *such* men in the future.

> I have six honest TAPPI men
> (They taught me all I knew)
> Their names are What and Why and When
> And How and Where and Who.

Ladies and Gentlemen, you can't beat them.

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February 21–24, 1955

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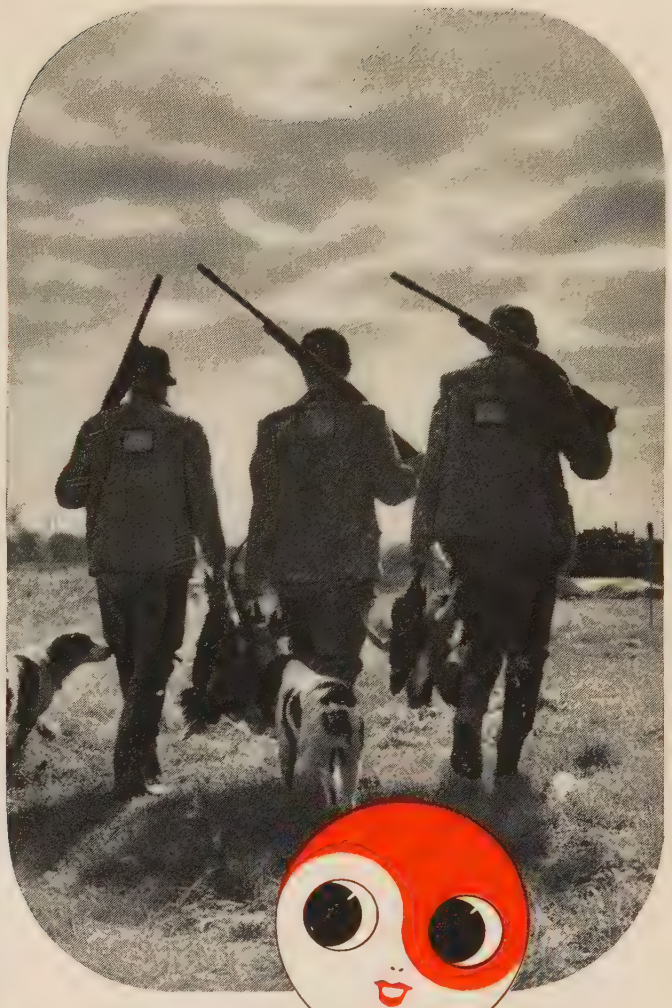
DRYER FELTS



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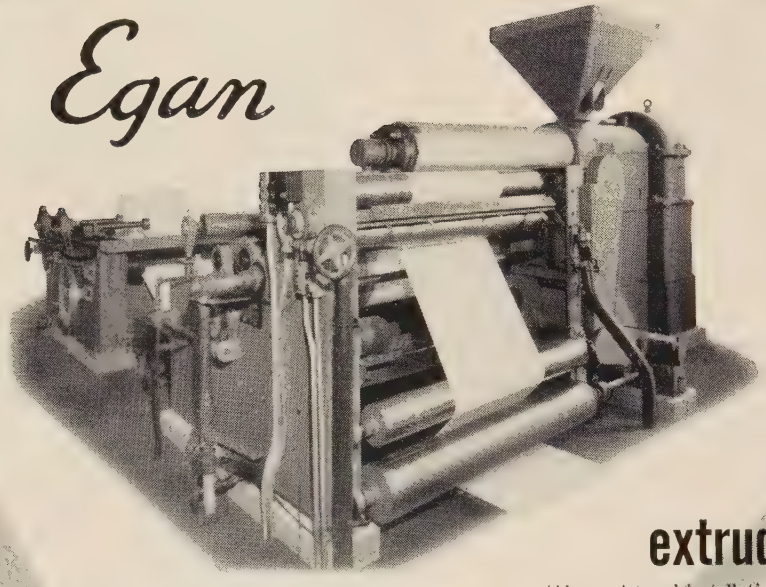

polyethylene extruder-laminator

(Above pictured installation at the Milford, N. J. plant of RIEGEL PAPER CORPORATION)

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Combining in one unit, in engineered balance, two famous units—The Egan Extruder and the Egan Laminator. Planned for your current—or expanding—production, available in varying sizes—from 24″ Pilot Plant Size to 96″, 1000 feet per minute continuous operation. Machines are capable of coating on paper and paperboard, cellophane, foil, glassine and cloth.

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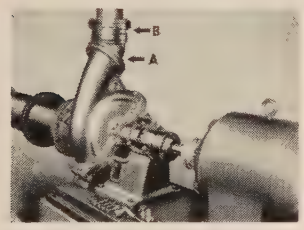
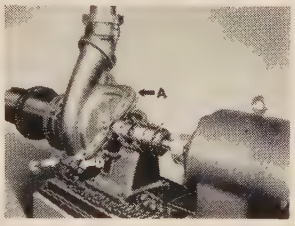
NEW Goulds Stock Pump

brings new maintenance economy

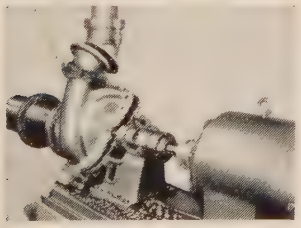
Follow through the simple operation of this newly-designed, hinged-cover casing, as shown in these pictures, and you'll see how completely it serves the requirement of better and faster maintenance.



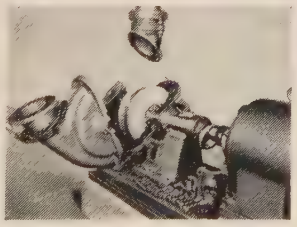
1. You remove bolts connecting discharge elbow and pump casing (A). To get clearance and save gasket, you telescope the discharge elbow into discharge connection by a simple jacking arrangement (B).



2. Remove bolts connecting upper and lower halves of casing (A). Loosen top nuts (C) and raise upper half casing on hinge pin. Tightening hex nuts (D) raises casing off side-plate locks.



3. Attach chain falls and continue to raise casing. (On smaller sizes you can swing back the top casing half with a rod or pipe through the cored hole in casing web.)



4. With pump completely open, you remove bearing cap, disconnect coupling and lift rotating element out. And you've had to break no piping connections.

Bulletin 723.1 describes *all* the Fig. 3135 features that add up to advantages for you. Just write us, or use the coupon, and we'll send you a copy promptly.

Goulds PUMPS INC.
Seneca Falls
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In less than ten minutes one man alone can swing back the entire upper half of the new Goulds Fig. 3135 paper stock pump and check or remove the rotating element—*without disturbing pipe connections.*

Another new feature is the *centerline discharge.* The vertical centerlines of both suction and discharge are the same. This eliminates the need for right- and left-hand pumps, which saves on parts inventory. It also eliminates air binding and insures steady flow. If you need horizontal discharge, you merely rotate the discharge elbow at the top of the casing 180°.

You'll find other practical innovations in this new stock pump—innovations that mean your maintenance men can now easily do their inspecting and overhauling in much less than the time your machines are down for wire changes.

Fig. 3135 Features

Separate liquid end—available in bronze-fitted, all iron, all bronze and various stainless steel constructions.

Centerline discharge located at highest point in casing eliminates air binding.

Diagonally-split hinged casing gives quick access to rotating element, including bearing assembly.

Nonclogging impeller has special warped vane and heavy renewable side plates. Built for heavy duty.

Axial adjustment maintains proper clearance between impeller and suction side plate.

Rotating element same as in the Goulds Fig. 3105 stock pump, eliminating double inventory where both styles of pumps are in use.

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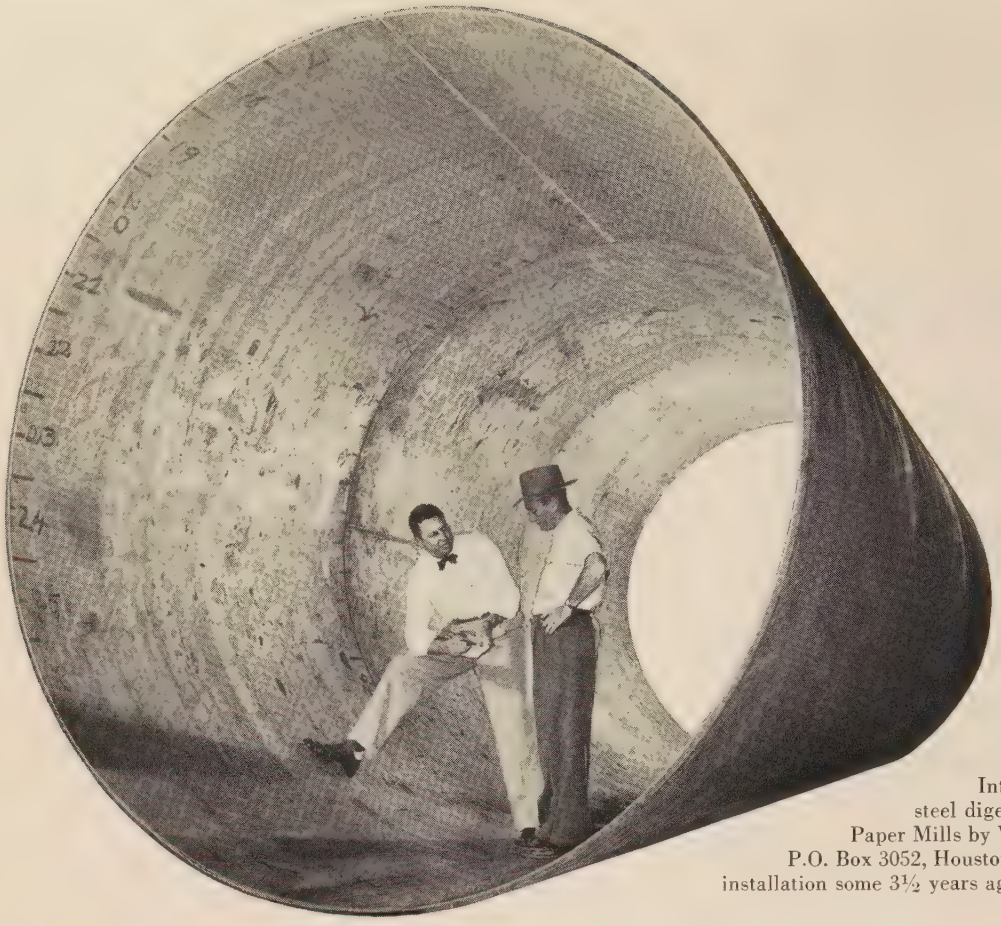
Continuous hydrogen peroxide bleaching at 25-40% density is increasingly used for groundwood and chemical pulps in crumb or sheet form. High density operation has reduced chemical cost and floor area requirements. Groundwood bleaching is now more efficient than ever. Chemical and semi-chemical pulps are super-bleached to high brightness with improved aging characteristics not otherwise attainable. For detailed information write for Becco Bulletin No. 48.

Buffalo Electro-Chemical Company, Inc.

DIVISION OF FOOD MACHINERY AND CHEMICAL CORPORATION

Sales Agent: BECCO SALES CORPORATION, Station B, Buffalo 7, N.Y.
Buffalo • Boston • Charlotte • Chicago
New York • Philadelphia • Vancouver, Wash.



Interior of Lukens Inconel-Clad steel digester, manufactured for Crossett Paper Mills by Wyatt Metal and Boiler Works, P.O. Box 3052, Houston 1, Texas. Since its installation some 3½ years ago, annual corrosion is nil.

Digester corrosion rate: Inconel, nil—Carbon Steel, 62 mils

Consider the experience of Crossett Paper Mills, Crossett, Ark.

They have used various forms of carbon steel and different alloys including Lukens Inconel-Clad for digesters.

Eight mild steel digesters show an average corrosion rate of 62 mils per year. The Inconel-Clad digester shows no measurable corrosion.

The evidence is clear, not only in the Crossett installation but in several other well known mills.

Judging by mill experience in general, Inconel shows greatly improved resistance to alkaline pulp digester corrosion as compared to other materials of construction.

If you want the latest data for *any* type of corrosion-resisting equipment for alkaline pulping processes, write our Corrosion Engineering Section. They will help you work out the solution for your specific conditions.

The INTERNATIONAL NICKEL COMPANY, Inc.
67 Wall Street New York 5, N. Y.

INCO TRADE MARK **Nickel Alloys**

MONEL® • "R"® MONEL • "K"® MONEL
"KR"® MONEL • "S"® MONEL • INCONEL®
INCONEL "X"® • INCONEL "W"® •
INCOLOY® • NIMONIC® ALLOYS • NICKEL
LOW CARBON NICKEL • DURANICKEL®

Inconel... *for longer service life*

COATING CONTROL

It is said that a wise Sioux medicine man once discussed the matter of making a living with *Miranda Aurantia,* the garden spider, who told him: "Coating control is the all-important factor. With it, I wrap up job after job very profitably. Without it, I wouldn't be worth a 'sou'."

There's something extremely significant in that for you, Mr. Papermaker—since it's your business to provide satisfactory finished sheet to meet numerous specifications. The importance of coating control is something you have occasion to recognize daily.

And that makes us confident we can serve you to your great advantage—for we have lived closely with paper coating problems for many years, and have developed the most complete line of paper coating chemicals available. These Nopco* products are specially designed to help you solve problems of viscosity control, foaming, even distribution, dusting, gloss, and moisture content.

When our technical representative calls, let him show you how Nopco coating aids—defoamers, emulsifiers, plasticizers, and eveners—can help you wrap up job after job satisfactorily...meeting all of your customers' specifications with just the finished sheet required.

LOOK TO NOPCO AS YOUR SOURCE OF SUPPLY FOR:

Foam Killers • Sulfated Oils • Emulsified Resins • Coating Compounds • Wax Emulsions and Emulsifiers • Rewetting Agents • Insoluble Metallic Soap Dispersions • Sheet Formation Aids • Plasticizers • High Free Rosin Sizes • Pitch Dispersants

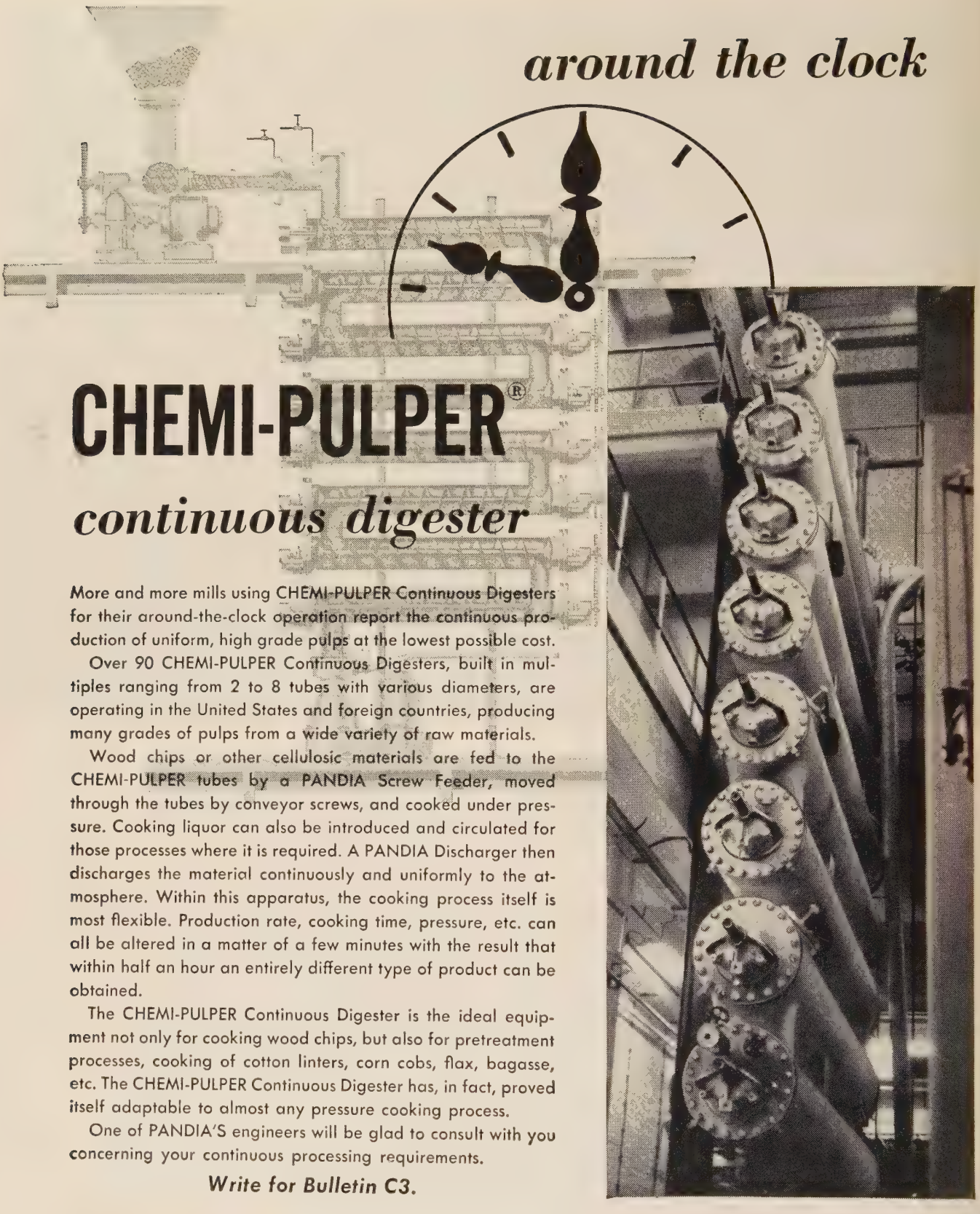
* Registered U. S. Pat. Off.

NOPCO

Chemical Company, Harrison, N. J.

Branches: Boston • Chicago • Cedartown, Ga. • Richmond, Calif.

around the clock



CHEMI-PULPER®

continuous digester

More and more mills using CHEMI-PULPER Continuous Digesters for their around-the-clock operation report the continuous production of uniform, high grade pulps at the lowest possible cost.

Over 90 CHEMI-PULPER Continuous Digesters, built in multiples ranging from 2 to 8 tubes with various diameters, are operating in the United States and foreign countries, producing many grades of pulps from a wide variety of raw materials.

Wood chips or other cellulosic materials are fed to the CHEMI-PULPER tubes by a PANDIA Screw Feeder, moved through the tubes by conveyor screws, and cooked under pressure. Cooking liquor can also be introduced and circulated for those processes where it is required. A PANDIA Discharger then discharges the material continuously and uniformly to the atmosphere. Within this apparatus, the cooking process itself is most flexible. Production rate, cooking time, pressure, etc. can all be altered in a matter of a few minutes with the result that within half an hour an entirely different type of product can be obtained.

The CHEMI-PULPER Continuous Digester is the ideal equipment not only for cooking wood chips, but also for pretreatment processes, cooking of cotton linters, corn cobs, flax, bagasse, etc. The CHEMI-PULPER Continuous Digester has, in fact, proved itself adaptable to almost any pressure cooking process.

One of PANDIA'S engineers will be glad to consult with you concerning your continuous processing requirements.

Write for Bulletin C3.

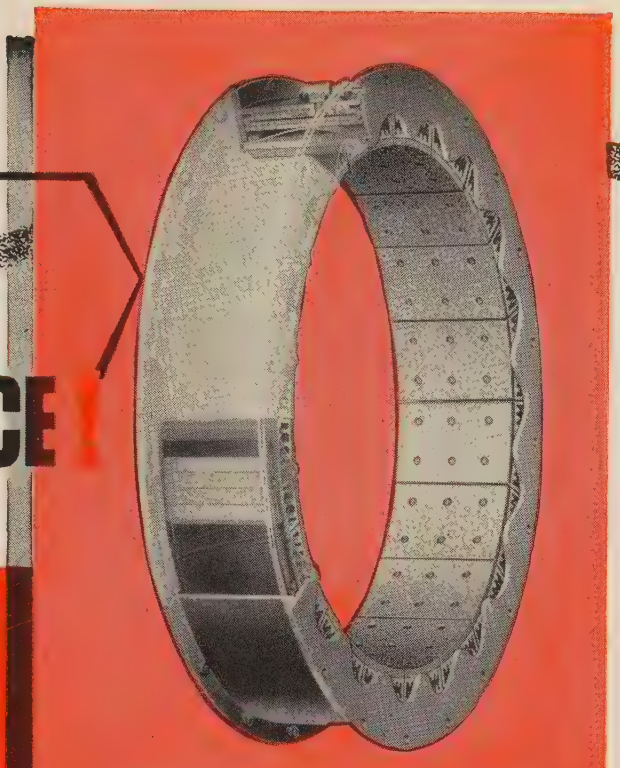
Manufactured and Sold in Canada by
THE ALEXANDER FLECK LIMITED, OTTAWA, CANADA.

PANDIA

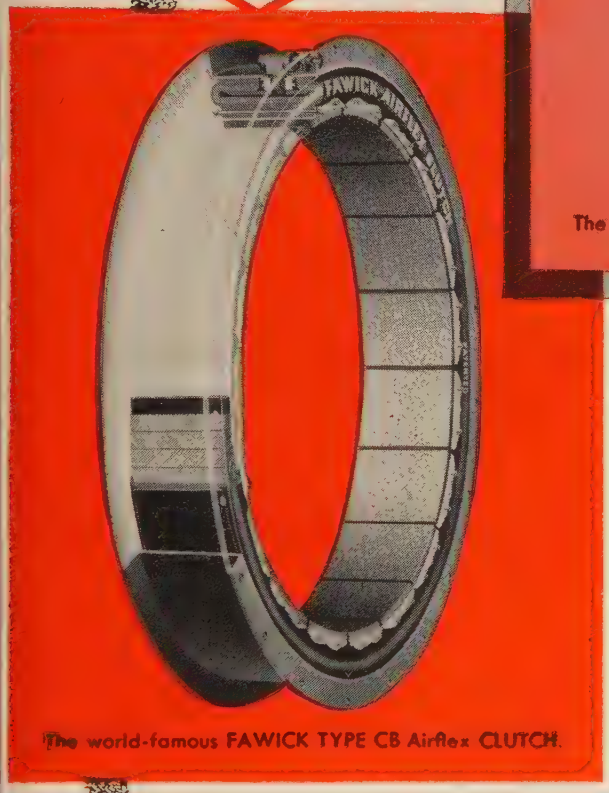
PANDIA INC.

122 EAST 42nd STREET • NEW YORK 17, N. Y.

FAWICK GIVES YOU YOUR CHOICE



The NEW completely ventilated FAWICK TYPE VC Air-Ring CLUTCH.



The world-famous FAWICK TYPE CB Airflex CLUTCH.

● *Every industrial clutch application requires specific operating characteristics for highest efficiency and safety.*

Continuing the FAWICK policy of supplying industry with the best in clutches and brakes, FAWICK AIRFLEX now provides, in addition to the world-famous FAWICK TYPE CB, the new completely ventilated FAWICK TYPE VC Air-Ring CLUTCH.

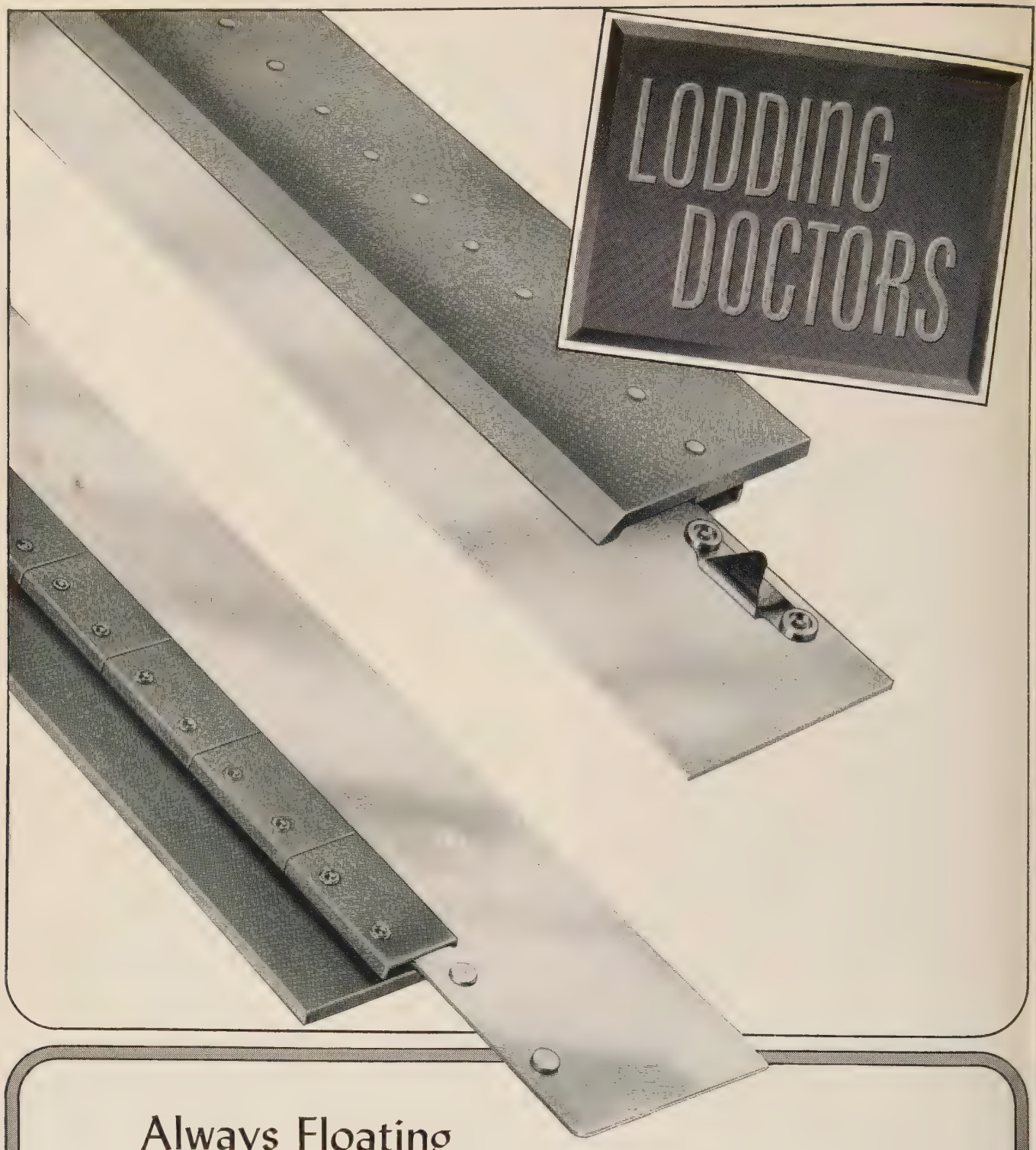
Clutch design features found only in this new VC CLUTCH include (1) cooler operation inherent in drum clutch design; (2) isolation of the operating tube from the heat-generating friction surface; (3) riveted, replaceable friction lining; (4) loose, expanding operating tube which can be replaced without removing the clutch from the shaft.

This FAWICK rigid-type VC CLUTCH is unmatched for heavy-duty service where high starting loads or sustained slippage generate high operating heat that lowers operating efficiency and shortens clutch life. The cooler operation and other advantages found in the FAWICK TYPE VC provide "new clutch" performance throughout a long, maintenance-free life.

For Further Information write for Bulletins 400-A and ML-102.

FAWICK AIRFLEX DIVISION
FAWICK CORPORATION
9919 CLINTON ROAD • CLEVELAND 11, OHIO

FAWICK Airflex
INDUSTRIAL CLUTCHES AND BRAKES



Always Floating

LODDING K-4 Blade Holder gives additional blade flexibility . . . free riding, it hugs the roll from end to end . . . a marked advance in the floating blade principle . . . . K series holders and blades interchangeable . . . . no sacrifice of ruggedness . . . . no blade changing problems. Lodding Engineering Corporation, Worcester, Massachusetts. Represented by W. E. Greene Corporation, Woolworth Building, New York

value in a fine product

reflects the experience and skills of its makers.

value in Fourdrinier wires is a matter of record ... paper quality and production records in mills throughout America reflect the fact that Appleton Wires are Good Wires!

APPLETON WIRE WORKS, INC., APPLETON, WISCONSIN

Mathieson Chlorine: *worth its salt*

Row upon row of mercury cells characterize the uniform high purity of Mathieson chlorine. These cells decompose a salt solution by electrolysis to form a sodium amalgam and wet chlorine gas. Subsequent processes dry the gas, liquefy and cool it, resulting in chlorine approximately 99.9% pure. Above is one of five producing units from which Mathieson supplies quality chlorine to industries from Canada to the Gulf.

Consistent product quality is typical of all Mathieson chemicals. In addition, Mathieson offers consumers the protection of multi-plant production facilities . . . 3 major alkali plants, 7 sulphuric acid plants, 6 caustic soda plants, 3 ammonia plants . . . as well as practical technical assistance with chemical handling and application problems.

In planning your chemical requirements call in your Mathieson representative. Perhaps you can buy to better advantage from one of America's largest producers of basic industrial chemicals.

OLIN MATHIESON CHEMICAL CORPORATION

INDUSTRIAL CHEMICALS DIVISION

BALTIMORE 3, MARYLAND

MATHIESON

CAUSTIC SODA • SODA ASH • CHLORINE • SULPHURIC ACID • SULPHUR • AMMONIA • NITRATE OF SODA • BICARBONATE OF SODA • CARBON DIOXIDE • SODIUM CHLORITE • CALCIUM HYPOCHLORITE
ETHYLENE OXIDE • ETHYLENE GLYCOL • DIETHYLENE GLYCOL • TRIETHYLENE GLYCOL • POLYGLYCOLS • DICHLOROETHYLETHER • ETHYLENE DICHLORIDE • METHANOL • SODIUM METHYLATE • ETHYLENE DIAMINE

Scrap your **WASHBOARD**

by control of moisture and adhesive penetration

with **KELSIZE®**

Washboard formation in corrugated board is caused by excessive moisture being absorbed by the liner after it has been bonded to the flutes. This condition can be improved by reducing the excess moisture at the glue line through the use of a small percentage of KELSIZE which will insure uniform adhesive application, control of adhesive penetration, and uniform viscosity.

Not only is washboarding eliminated or greatly reduced through control of these factors but machine speeds can be increased, a stronger and more uniform bond obtained and scrap reduced.

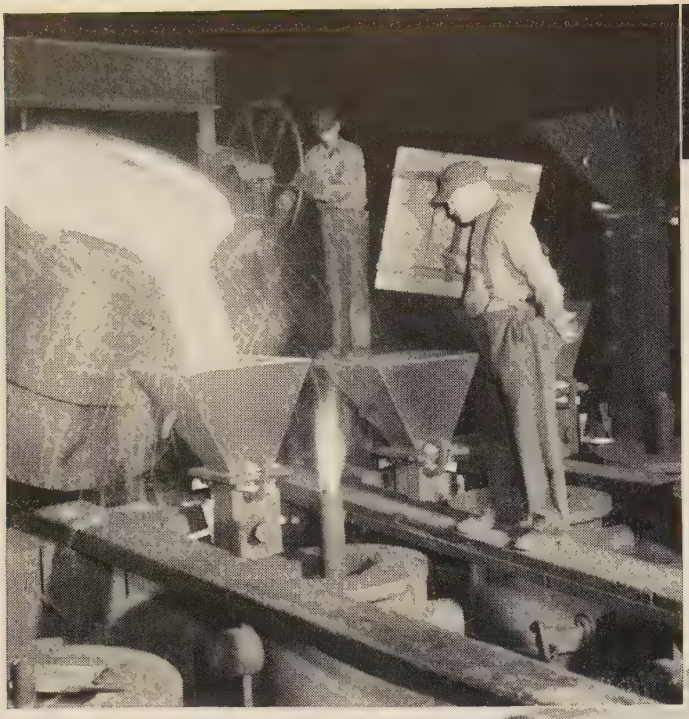
If washboarding is a problem, why not call the nearest Kelco office for the services of one of our experienced paper technical men?

Precisely engineered for specific uses, Kelco algin products are manufactured to absolutely uniform standards by the Kelco control procedure, which includes 46 distinct tests.

KELSIZE® . . . *a product of* **KELCO** *company*

20 N. Wacker Drive, Chicago 6, Ill. • *Nassau Street, New York 5, N. Y.* • *530 W. Sixth Street, Los Angeles 14, Calif.*

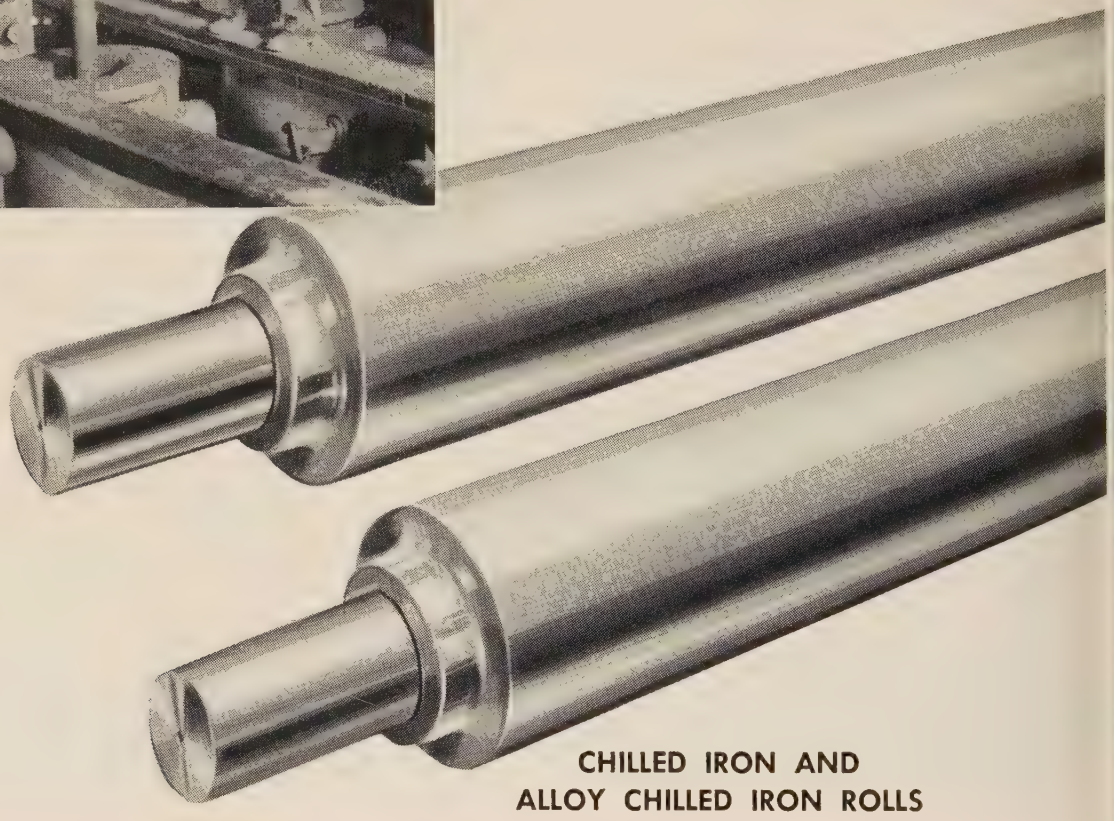
Cable Address: Kelcoalgin — New York



ROLLS

RIGIDLY SUPERVISED

from pouring pit to paper mill



CHILLED IRON AND ALLOY CHILLED IRON ROLLS

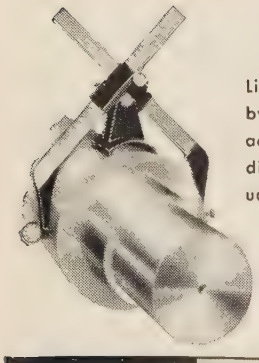
LOBDELL UNITED manufactures a wide variety of rolls for the Paper and Allied Industries . . .

Comprehensive technological experience, advanced engineering skill, modern production facilities and recognized leadership in the design and construction of rolls are your guarantee of complete satisfaction.

Lobdell Plain Chilled Iron Rolls have a uniformly hard surface highly resistant to abrasion and deformation under load. They give longer service for machine calendering. Alloy Chilled Iron Rolls for water finish or high pressure stacks are harder and more resistant to corrosion and abrasion than ordinary rolls.

When planning replacements or installation of new equipment, you'll find it advantageous to specify LOBDELL UNITED.

Detailed information gladly sent upon request.



MICROMETER ROLL CALIPERS

Light weight permits easy handling by one man, and they are readily adjusted to a wide range of roll diameters. Micrometer dial is graduated in thousandths.

- CHILLED IRON ROLLS
- MACHINE CALENDER STACKS
- ROLL GRINDING MACHINES
- ROLL CALIPERS
- KNIFE GRINDERS
- ABRASIVE CUT-OFF SAWS

1836 **LOBDELL UNITED COMPANY** **1954**

WILMINGTON 99, DELAWARE

A SUBSIDIARY OF UNITED ENGINEERING AND FOUNDRY COMPANY

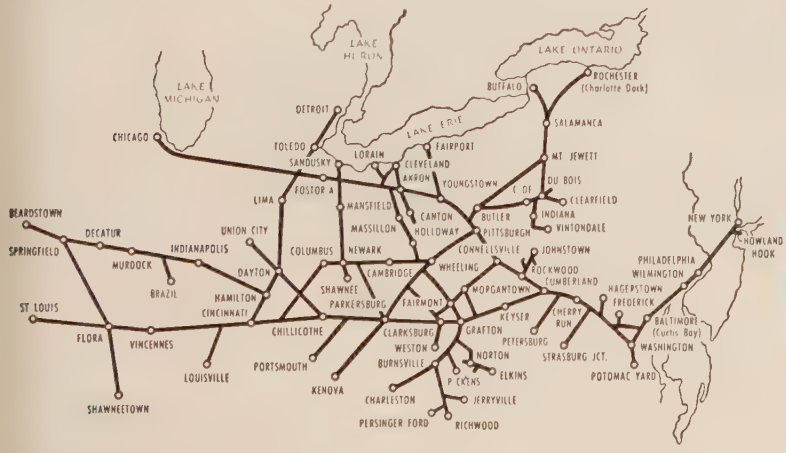
Your "burning question" is quickly answered—with

B&O Bituminous

Whether your specific question concerns power, coking, steam, or space heating, you'll find the perfect answer among the wide variety of Bituminous coals in Baltimore & Ohio territory. Here lies an almost inexhaustible source of low-cost heat and energy.

The benefits of B&O Bituminous are many. Highly mechanized mines keep production costs low, size and quality uniform. Closeness to America's industrial heart means economical transportation. The ease of storing coal eliminates the need for expensive facilities. And new methods and devices take further advantage of the burning characteristics of Bituminous.

ASK OUR MAN! He will help you find the exact coal for your purpose, and explain the best way to burn it. You'll be amazed at the efficiency, economy, and cleanliness of B&O Bituminous today.

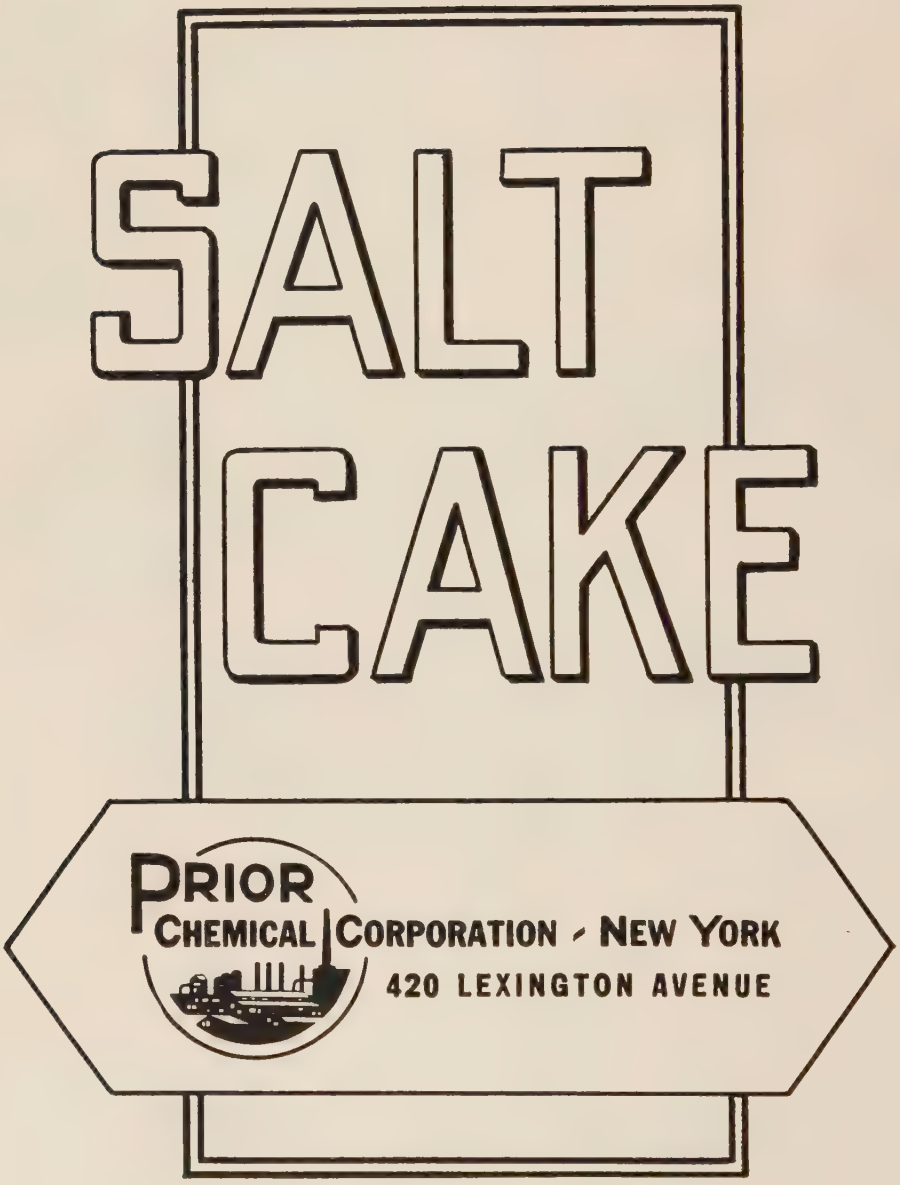


LINKING 13 GREAT STATES WITH THE NATION

B&O

BALTIMORE & OHIO RAILROAD

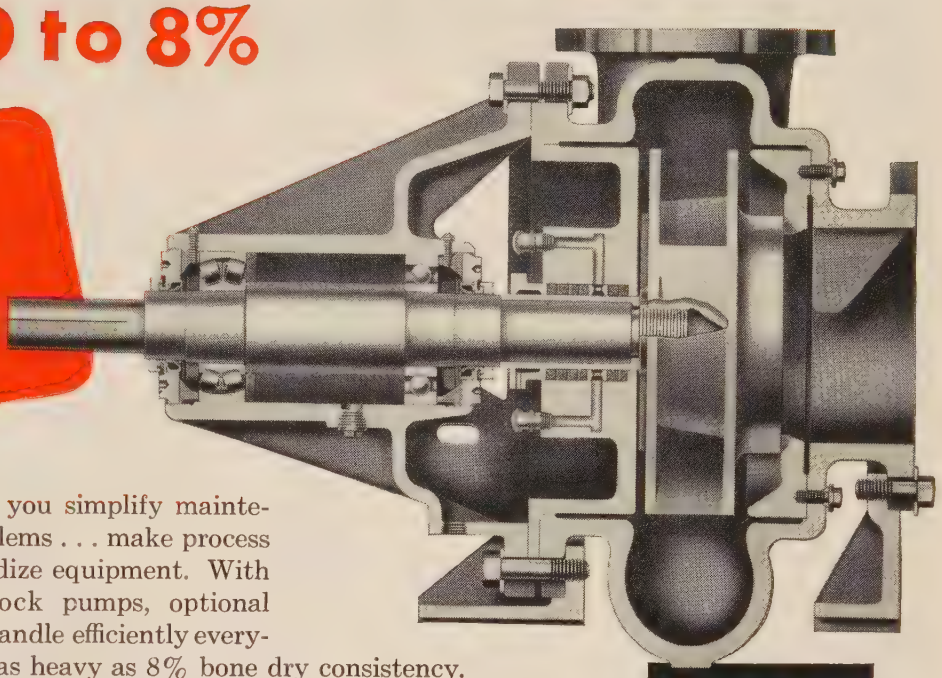
Bituminous Coals for Every Purpose


SALT
CAKE
PRIOR
CHEMICAL CORPORATION - NEW YORK
420 LEXINGTON AVENUE

One Pump

handles stock consistencies from 0 to 8%

ALLIS-CHALMERS
Paper Stock
PUMP



0 to 3%

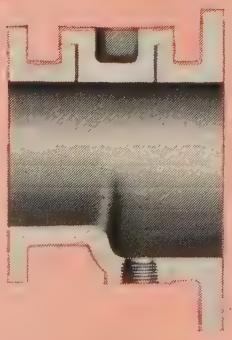
With this one basic pump you simplify maintenance and spare parts problems . . . make process changes easier . . . standardize equipment. With Allis-Chalmers paper stock pumps, optional equipment enables you to handle efficiently everything from liquor to stock as heavy as 8% bone dry consistency.

This basic pump (right) handles liquor and stock up to approximately 3%. With the optional equipment shown below, this pump has successfully handled stock as heavy as 8%. This wide choice makes it possible for your Allis-Chalmers pump representative to recommend exactly the right combination to give you greatest production at lowest cost.

Optional Equipment That Fits Your Requirements

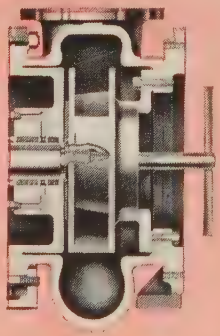
3 to 5%

Suction Nozzle Piece with special offset increaser is designed to prevent stock dewatering, cut suction pipe friction. Features removable handhole cover for cleaning.



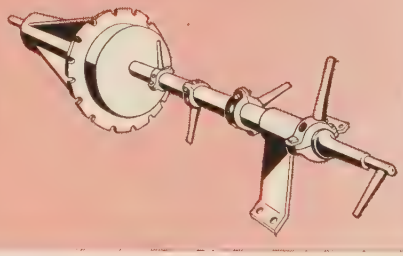
5 to 6%

Feeder Vane Assembly with 16-inch suction adapter (on all sizes up to 10-inch discharge) eases flow at suction. Vane rotates with impeller, breaks up lumps, aids stock movement into impeller eye.



6 to 8%

***Hi-Density* Feeder** is separate unit in stock chest. Rotating vanes force stock into pump, break up lumps, improve flowability of heavy stocks.



Hi-Density is an Allis-Chalmers trademark.

Remember, Allis-Chalmers can supply the complete pumping unit — pump, motor, control and drive — assembled and ready to run. Next time you have a stock pumping problem, call your Allis-Chalmers representative, or write Allis-Chalmers, Milwaukee 1, Wisconsin. Ask for Bulletins 52B7112 and 08B6725.

A-4320

A-C ALLIS-CHALMERS

ALLIS-CHALMERS

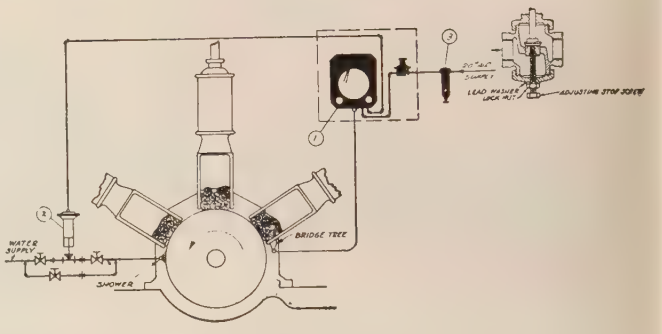
Taylor control keeps its nose to the grindstone

AND that's why it's so successful in detecting temperature variations in the groundwood. Location of the thermal element is all important to the successful operation of Automatic Temperature Control for wood pulp grinders, and Taylor has developed systems that are adaptable to all types—Pocket, Hydraulic Magazine, Continuous Magazine, Semi-Magazine, or Rotary Continuous.

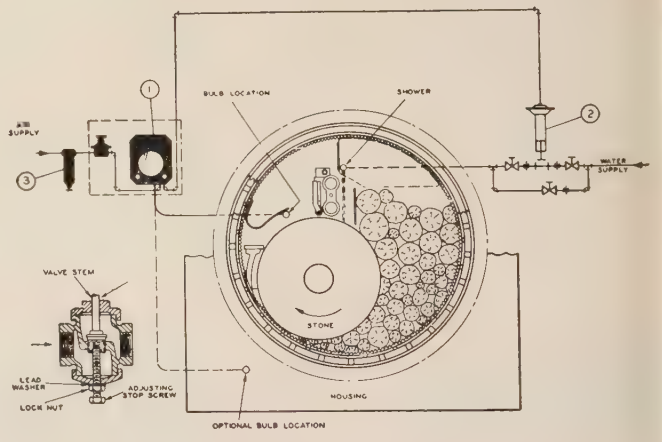
In the Taylor system the temperature sensitive bulb is located where it receives a constant shower of stock thrown from the stone by centrifugal force. It extends across the entire width of the stone, and the vapor-filled thermal system responds to the hottest spot across its face. Temperature is controlled by a Taylor FULSCOPE* Recording Temperature Controller which throttles a valve in the shower water supply line. This simple, practical system conserves stone life by preventing excessive temperature rises; increases production by maintaining the maximum temperature consistent with the pulp quality desired; decreases power consumption by over 6% per ton; relieves the operator for other duties.

This is just one phase of paper manufacture where Taylor controls are doing the job better, faster and more economically. Your Taylor Field Engineer will be glad to advise you on your problem—or write Taylor Instrument Companies, Rochester, N. Y., and Toronto, Canada. *Instruments for indicating, recording and controlling temperature, pressure, flow, liquid level, speed, density, load and humidity.*

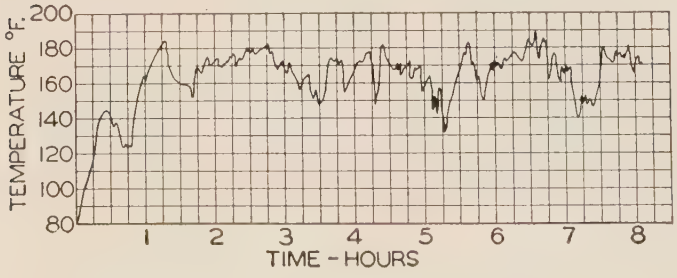
*Reg. U.S. Pat. Off.



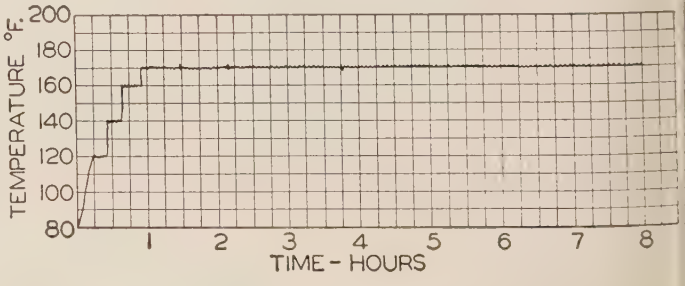
Pocket Type Grinder, showing location of bulb under bridge tree.



Rotary Continuous Type Grinder. Bulb installed underneath and at end of deflecting plate.



A typical plotted record of hand controlled grinding temperatures. Note rapid fluctuations, causing stock to vary in color, freeness and tensile strength.



Taylor control holds grinding temperature within an average of ± 1 °F. Stone temperature can be brought up as gradually as desired after a shutdown by simply resetting control point.

Taylor Instruments MEAN ACCURACY FIRST

Proving Itself Everywhere . . .
The G BOND NORTON PULPSTONE

Advantages —

1. **EASIER TO BURR**
2. **HOLDS PATTERN LONGER**
3. **MORE UNIFORM GRINDING ACTION**

IN mill after mill the new G Bond Norton Pulpstone is demonstrating these advantages. Many mills have entered repeat orders because they find that this stone gives them the highest quality, cleanest pulp for longest periods. It is another Norton improvement to help you meet today's competitive conditions. Ask your Norton pulpstone engineer about the new G Bond stone in ALUNDUM and 38 ALUNDUM* abrasives.

NORTON COMPANY, WORCESTER 6, MASS.

Norton Company of Canada, Ltd.
Hamilton, Ontario

*Shown in illustration above

NORTON PULPSTONES

Making better products...to make other products better

Abrasives - Grinding Wheels - Grinding and Lapping Machines - Refractories - Porous Mediums - Non-slip Floors - Norbide Products

The superior quality of OK BRAND starches gives you improved tub, beater, and calender sizing. Better for coating and adhesives, too. When you make better paper at no extra cost — you've put more profit in your "paper work". Try OK BRAND and see! Discuss your special starch requirements with Hubinger's expert technicians.

the stamp of quality

ESTABLISHED IN 1881
THE HUBINGER COMPANY
KEOKUK, IOWA

New York • Chicago • Los Angeles • Boston • Charlotte

OK BRAND

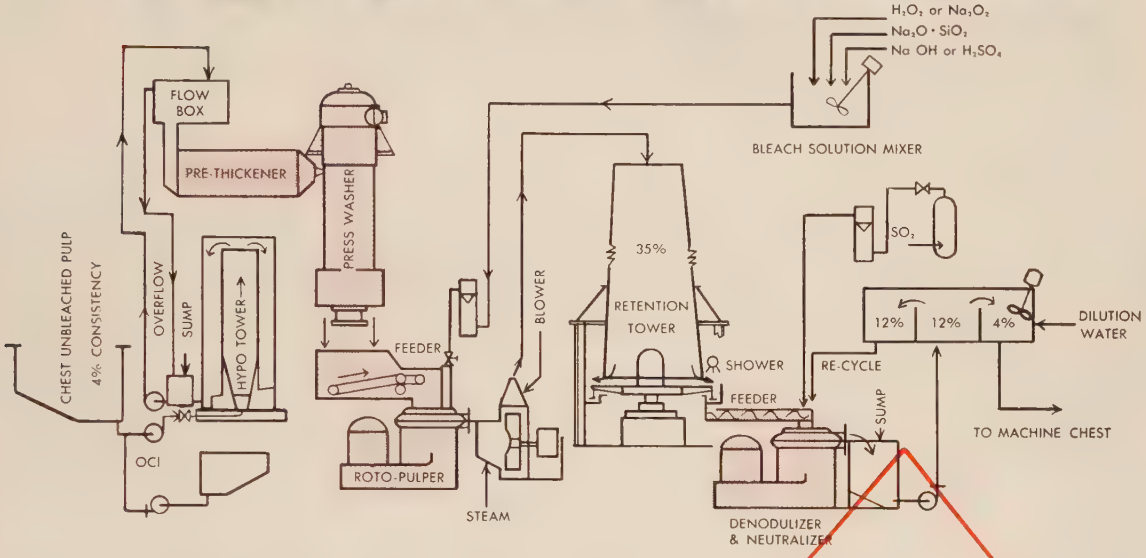
Try these top-quality starches for paper makers:

- OK BRAND Pearl
- OK BRAND E-Type Pearl
- OK BRAND Pearl 700
- OK BRAND Pre-Jel
- OK BRAND Thin Boiling Starch
- OK BRAND Oxidized Starches

now you can have both . . .

lower cost

higher brightness



in the new J-C groundwood bleaching system!

For four years J-C's single stage groundwood bleaching system has provided high brightness at reduced costs for various mills.

Now a new and better process . . . the dual-stage system . . . has been perfected by J-C engineers to give outstanding savings in chemical consumption and greater increases in brightness.

Look over this list of reasons and see for yourself how this new process produces a better product at a far lower cost.

fully continuous, precision controlled system
low initial investment
much lower operating costs per ton
minimum floor space
sharply reduced yield loss
maximum brightness
minimum color reversion
unchanged pulp physicals
one operator per shift
freedom from knots and "fish eyes"

Your nearest J-C representative will tell you how it is done!

The Tayler Corp.
46 Trinity Place
New York 6, N. Y.
Phone BO 9-6496

Homad Services Ltd.
1445 Crescent St.
Montreal 25, P.Q.
Phone Belair 5419

John D. Homan
714 S. Orleans Ave.
Tampa 6, Fla.
Phone Tampa 8-3952

M. O. Grove & Co.
310 Sacramento St.
San Francisco 11, Calif.
Phone Yukon 6-1611

Jas. Brinkley & Co.
417 Ninth Ave. So.
Seattle 4, Wash.
Phone Maine 0062

Frank C. Bacon
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Phone KE-7098

J-C

JACKSON & CHURCH CO. SAGINAW, MICHIGAN

Work well done since eighty-one

ORISKANY FELT'S

Modernization and expansion program

...geared to meet every challenge in paper-making progress!

The paper industry has moved ahead with giant strides in the last few years with new mills, new equipment, new techniques. And here at Oriskany, we are meeting every new technical advance in paper-making with the most modern felt-making equipment available, and a full-equipped textile laboratory for research and development projects.

Our five new large looms — including a 600″ loom — and a 300″ dryer provide ample capacity for weaving and finishing felts for the largest high-speed machines projected by machine builders. Completely new spinning equipment assures consistently uniform felt yarns. Fulling Mills of our own design have been added for felting and shrinking large felts. And in our modern laboratory, close controls are maintained in every manufacturing step from raw wool processing to finished felt. Here, too, new materials are tested, new felts are developed, to meet the needs of an ever-growing industry!

Our experienced sales engineers will welcome the opportunity to show you how Oriskany Felts are ready to go to work for you . . . to help you produce quality paper products *better . . . faster . . . at less cost!*

First choice–because they last

Oriskany

WATERBURY FELTS

H. WATERBURY and SONS COMPANY • ORISKANY, NEW YORK

Here's how you can profit

with Du Pont Peroxides and Bleaching Processes

. . . in bleaching sulfate pulp

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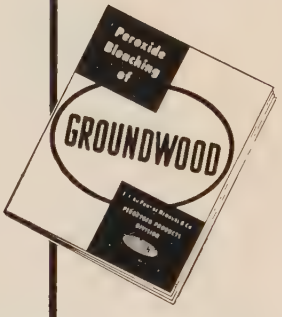

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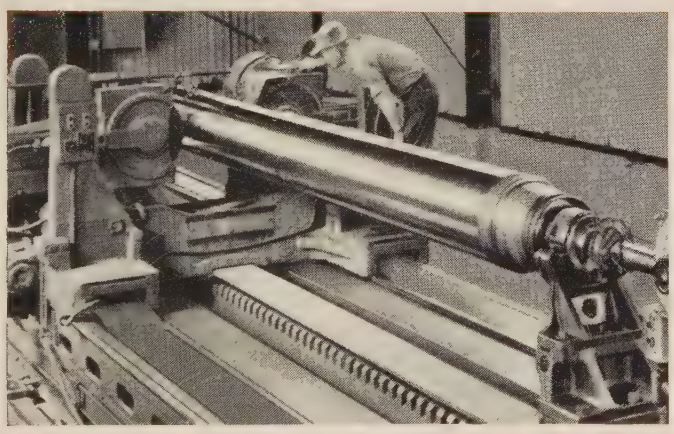

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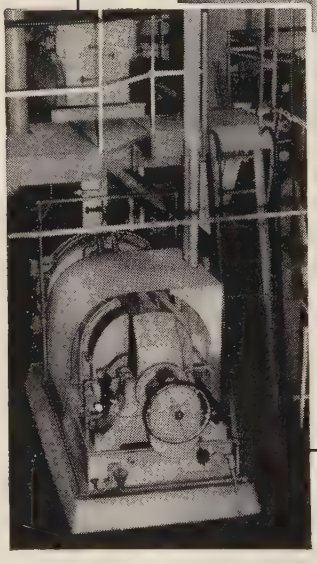

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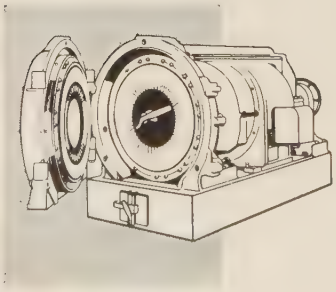

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Effect of Medium in the Acetylation of Cellulose

R. C. BLUME and F. H. SWEZEY

The acetylation of high molecular weight cellulose without degradation has been carried out in pyridine–acetic anhydride systems. Hess and Ljubitsch [*Ber.* 61B: 1460 (1938)] found, however, that even with most elaborate swelling pretreatment of the cellulose several weeks were required for complete reaction. Cellulose also acetylates without degradation in the acetic anhydride–potassium acetate system. This reaction, too, is relatively slow. Twenty-four or more hours are required for production of cellulose triacetate. It has now been found that purified high molecular weight cellulose can be acetylated rapidly and without degradation by the acetic anhydride–potassium acetate system using dialkylamides or gamma-lactones as the reaction medium. The new media give a 20- to 30-fold increase in reaction rate even when the celluloses used are given no special pretreatment. The effectiveness of the media in promoting the reaction correlates with the known dielectric constants, which permits postulation of reaction mechanism. These media have also been applied effectively in the acid-catalyzed acetylation of cellulose with acetic anhydride.

THE reluctance of cellulose to undergo acetylation has long been considered one of its more remarkable properties. The pyridine-acetic anhydride system, which is capable of acetylating starch to the triacetate in about 1 hr. by the method of Pacsu and Mullen, requires several weeks for the complete acetylation of cellulose according to Hess and Ljubitsch [*Ber.* 61B: 1460–1462 (1928)]. The potassium acetate–acetic anhydride system is somewhat more successful, yet requires more than 24 hr. for the complete acetylation of cotton linters. The degradative acid-catalyzed acetylations of cellulose are known to reach completion in several hours, but even this reaction proceeds at a satisfactory rate only after the cellulose has been suitably pretreated with swelling reagents such as water or sulphuric acid, usually in the presence of acetic acid.

Elod and Schmid-Bielenberg [*Z. Phys. Chem.* B25: 27 (1934)] showed many years ago the relatively large effect of water pretreatment on the rate of reaction of cellulose with acetic anhydride in the presence of sulphuric acid. Their theoretical explanation of the pretreatment action, still generally accepted, is that water and acetic acid greatly reduced the hydrogen bonding between cellulose chains and permit more rapid diffusion of acetic anhydride into the inner structure of the cellulose. The results of these early workers indicated nearly an eightfold increase in reaction rate as the water content of the cellulose was increased from 6.5 to 24.4%. Many other workers have demonstrated that pretreatment with caustic solution, water, or acetic acid markedly increases the rate of uncatalyzed reactions as well as those catalyzed with pyridine or with potassium acetate. These pretreatments are a considerable disadvantage in that they add to the complexity of the acetylation and must be varied in detail for each of the many celluloses used as raw material for acetylation.

It has now been discovered at the Benger Laboratory of E. I. du Pont de Nemours & Co. that the rate of acetylation of cellulose with acetic anhydride is remarkably accelerated by the presence of a variety of organic solvents of relatively high dielectric constant. This increase in reaction rate is observed even in the absence of any special pretreatment.

The initial work in this field was concerned with the uncatalyzed acetylation reaction of cellulose with acetic anhydride. It was known from the work of Bernoulli, Schenk, and Hagenbuch [*Helv. Chim. Acta* 13: 534-571 (1934)] that this reaction was extremely slow. These workers found that only 38.2% combined acetic acid was introduced after 261 hr. of reaction at refluxing temperature and considerable degradation of the cellulose also took place. The use of dimethylformamide as medium for this reaction was suggested by the work of Kress and Bialkowsky [*Paper Trade J.* 93: 35 (1931)]. They found that formamide had a very large swelling power for cellulose and we accordingly selected dimethylformamide as the simplest derivative of this substance which does not react with acetic anhydride at high temperatures. Since the work of Stamm and Tarkow [*J. Phys. Colloid Chem.* 54: 745 (1950)] suggests that compounds of high dielectric constant rather generally act as swelling agents for cellulose, the second solvent selected for study was gamma-butyrolactone.

Table I. Effect of Media on the Uncatalyzed Acetylation of Cellulose (5 G.)

Medium	*Combined acetic acid, %*
180 ml. Ac_2O	3.4
170 ml. γ-butyrolactone + 30 ml. Ac_2O	18.6
170 ml. dimethylformamide + 30 ml. Ac_2O	15.8

As is shown by Table I, these substances do indeed have a remarkable effect on the rate of acetylation in the absence of either acidic or basic catalyst. These reactions were all carried out for a period of 5 hr. at refluxing temperature with 5 grams of commercial acetylating cellulose, Buckeye linters. It is of interest that neither of these reagents caused apparent swelling of the cellulose.

The results do not disagree with the popular notion that polar substances influence the reaction rate of cellulose by breaking hydrogen bonds between cellulose chains, thus permitting freer access of the acetic anhydride. At the same time, it should be pointed out that these results, as well as those reported below, may be explained on the basis of the Ingold S_N^2 mechanism suggested by V. Gold [*Trans. Faraday Soc.* 1948,506] for the reaction of acetic anhydride and water. Such

R. C. BLUME and F. H. SWEZEY, Benger Laboratory, E. I. du Pont de Nemours & Co., Inc., Waynesboro, Va.

reactions are quite generally accelerated by an increase in dielectric constant of the environment.

Basic catalysts and particularly potassium acetate have been viewed with some interest in the acetylation of cellulose with acetic anhydride because of the fact that such reactions are nondegradative to cellulose [Haller and Ruperti, U. S. pat. 1,930,895 (Oct. 17, 1933)]. It has been found, however, that in the absence of specific pretreatments cellulose reacts only slowly with potassium acetate and acetic anhydride.

Table II. Effect of Dimethylformamide on Acetylation Catalyzed by Potassium Acetate

Acetic anhydride, ml.	*Dimethylformamide, ml.*	*Reaction time*	*Combined acetic acid, %*
300	0	1 hr.	30.2
150	150	15 min.	52.5
150	150	1 hr.	57.0
150	150	3 hr.	58.3

As indicated in Table II dimethylformamide is highly effective in increasing the reaction rate.

All of these reactions were carried out at the reflux temperature, approximately 140°C., with 10 grams of cellulose and 5 grams of potassium acetate. It will be noted here that, despite a very high initial rate, the reaction after 15 min. goes only very slowly toward completion. The rate in the final stages of reaction appears to be dependent upon the nature of the cellulose as is shown by the fact that wood pulp of acetylating grade is acetylated to 59.5% combined acetic acid content in less than 45 min. by this same reaction system and viscose rayon is completely acetylated under these conditions.

Table III. Effect of Dialkylamides and Gamma-Lactones on KOAc Catalyzed Acetylation

Activator	*Combined acetic acid, %*
Dimethylformamide	56.6
Dimethylacetamide	49.1
Diethylformamide	52.4
Diethylacetamide	46.3
Methylphenyl acetamide	50.1
Dibutyl butyramide	47.2
N-formyl morpholine	52.5
N-acetyl morpholine	55.6
N-propionyl morpholine	49.7
N-butyryl morpholine	48.6
γ-butyrolactone	53.8
γ-valerolactone	50.7

A variety of other N,N-dialkylamides, as well as gamma lactones, have been found approximately as effective as dimethylformamide in promoting the potassium acetate catalyzed acetylation. The materials used and results obtained are shown in Table III. In each case, a 5-gram sample of cotton linters was allowed to react for 1 hr. at reflux temperature, approximately 140°C., with a mixture of 75 ml. of acetic anhydride, 2.5 grams potassium acetate, and 75 ml. of the organic solvent. That these materials have rather specific action is shown by the fact that high-boiling ethers such as dimethoxytetraglycol and glycol diethyl ether actually have a marked inhibiting effect on the reaction, while high-boiling esters, such as triacetin and diethylene glycol diacetate, as well as high-boiling ketones, such as cyclohexanone and acetophenone have either a small inhibitory effect or no effect at all. Fatty acids, such as acetic acid and propionic acid, very nearly completely inhibit the reaction, probably through decrease of the basic strength.

In order to test the effect of varying the quantity of potassium acetate, three series of acetylations were carried out at 140°C. for 1 hr. on 5-gram samples of cotton linters. These experiments are summarized in Table IV.

Table IV. Effect of Potassium Acetate Concentration

KOAc, g.	*Combined acetic acid %, series 1 (150 ml. Ac_2O)*	*Combined acetic acid, %, series 2 (75 ml. Ac_2O: 75 ml. DMF)*	*Combined acetic acid, %, series 3 (20 ml. Ac_2O: 130 ml. DMF)*
0.0	2.0	9.0	7.0
0.1	2.6	18.9	16.3
0.5	9.6	32.1	32.4
1.0	20.7	46.9	43.5
2.0	27.7	52.1	..
2.5	36.0	52.4	46.1
5.0	46.3	46.3	..
10.0	49.9	43.0	49.7
20.0	51.7	38.2	58.0

These data indicate that the system with half its liquid volume consisting of N,N-dimethylformamide is a more effective acetylating medium than that consisting of pure acetic anhydride, except in those cases where the quantity of potassium acetate used exceeds the weight of the cellulose being acetylated. It may further be observed that the dimethylformamide system passes through a range of maximum reactivity and the strongest activating effect is noted when the quantity of potassium acetate is about half the weight of the cellulose being acetylated.

A large variety of metallic acetates, as well as other salts, have been employed in this reaction. Calcium, barium, magnesium, aluminum, and lithium acetate are entirely ineffective, while sodium acetate is far less effective than potassium acetate.

As pointed out above, the degradative acid-catalyzed acetylations of cellulose which are used commercially usually proceed at a satisfactory rate only after the cellulose has been lengthily pretreated with swelling

Table V. Effect of Sulphuric Acid Concentration on Acetylation Rate and Acetate Viscosity

Sulphuric acid, %	*Reaction time, sec.*	*Relative viscosity[a]*
5	120	1.182
2.5	220	1.223
1	672	1.097
0.25	2000	Insoluble

[a] Relative viscosity of a 0.092% solution in 92% acetic acid.

reagents such as water or sulphuric acid, usually in the presence of acetic acid. It has been found that this pretreatment may be entirely avoided, yet extremely rapid reactions were obtained by the use of a dialkylamide, such as dimethylformamide, instead of acetic acid as the reaction medium. At 140°C., for example, cotton

linters which had first been refluxed with dimethylformamide reacted rapidly with acetic anhydride in the presence of dimethylformamide and 1 to 5% sulphuric acid (based on cellulose weight) to give soluble primary cellulose acetates. This is illustrated in Table V.

In typical reactions, 5 grams of cotton linters in 100 grams of dimethylformamide were heated to 140°C. Upon reaching this temperature, 25 grams of hot acetic anhydride were added and this was followed by the addition of the indicated amount of sulphuric acid dissolved in 10 ml. of dimethylformamide. The cellulose rapidly went into solution and was immediately isolated by pouring the reaction mixture into water.

As is indicated here, the time of reaction and viscosity of the resulting product vary markedly with the quantity of sulphuric acid used as catalyst. The rate of reaction noted here may be compared to the several hours usually reported as being required for the acetylation of cellulose in the presence of sulphuric acid.

The order of addition of reagents is of great importance in carrying out this acid-catalyzed reaction. In an experiment in which the cotton linters were added last to a hot mixture of dimethylformamide and acetic anhydride containing 5% sulphuric acid based on cellulose weight, a soluble cellulose acetate was not obtained even in 30 min. at refluxing temperature. It appears likely that under these experimental conditions the sulphuric acid is converted to sulphoacetic acid, a much less satisfactory catalyst, before the cellulose is actually introduced. Satisfactory results have been obtained only when the sulphuric acid is introduced into the reaction mixture last.

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The Effect of Alkaline Pulping on the Lignin of *Eucalyptus regnans*

J. W. T. MEREWETHER

Lignin has been isolated from *Eucalyptus regnans*, an Australian hardwood, both by alkaline pulping and by ethanolysis, and the crude lignin purified to yield apparently homogeneous products. In addition, the alkali lignin has been converted to an ethanolysis product and in each case a series of derivatives has been prepared. The analyses of these three series of lignin derivatives suggest that alkaline pulping of *Eucalyptus regnans* results in the elimination of two alcoholic hydroxyl groups and a carbonyl group.

The year 1954 is an auspicious one to take stock of the extent of the understanding of the principles involved in alkaline pulping for it is exactly 100 years since this process was first patented by Watt and Burgess (*1*). During the century that has elapsed much investigational work has been carried out, but the position was summarized by Brauns in 1939 in these words (*2*): "The soda pulping process is the oldest chemical process for the production of pulp from wood but, in spite of this, very little is known about the actual chemical reactions taking place between the caustic soda and the various components of the wood." Today, 15 years later, those words still stand—very little is known. And, of these reactions, the one of particular interest to pulp mill chemists is the reaction taking place between sodium hydroxide and the protolignin of the middle lamella for it is the dissolution of the latter which brings about pulping. It is known that this protolignin is inert chemically, that it is insoluble in all solvents and is not dissolved by cold dilute aqueous alkali, whereas the alkali lignin of black liquor is soluble in alkali and certain organic solvents. Hence, it can be deduced that under the conditions of alkaline pulping protolignin undergoes some chemical change as a result of which it is converted to alkali lignin, but the nature of this change is still unknown.

Ideally, the first step toward solving this problem would consist of a chemical examination of the lignin before and after alkaline pulping. But this, of course, is impossible as protolignin cannot be isolated unchanged, and, indeed, many hold the view that protolignin does not exist free in wood, but is chemically linked with another wood component. Hence, a comparison of protolignin with alkali lignin can only be obtained by indirect means.

Now, just as lignin may be isolated by converting it to alkali lignin, so it may also be isolated in a number of other ways. In particular, it may be isolated in excellent yield by converting it to ethanol lignin, i.e., by subjecting wood to the action of ethanol in the presence of a catalyst. As protolignin cannot be isolated unchanged, an indirect approach to the problem would be to obtain both alkali lignin and ethanol lignin from matched samples of the same wood, and also to apply the ethanolysis reaction to the isolated alkali lignin. A knowledge of what chemical properties were common to the three lignins should make it possible to draw some inferences as to the composition of protolignin, while the differences should indicate some of the changes brought about by alkaline pulping. It is recognized that this is by no means ideal, but so long as the limitations are recognized it should be possible to obtain data of some value.

ALKALI LIGNIN (*3*)

The raw material used was *Eucalyptus regnans*, an Australian hardwood. It contained about 20% lignin and on soda pulping yielded about 50% of a practically lignin-free pulp. Hence, about 50% of the wood,

J. W. T. Merewether, Australian Paper Manufacturers, Ltd., Melbourne, Australia.

including 20% lignin had gone into solution in the black liquor. Fortunately, as is the case with spruce, the dissolved carbohydrates are mostly water soluble while the alkali lignin is merely alkali soluble, and acidification yielded a precipitate consisting mainly of alkali lignin. Treatment of this precipitate with dioxan yielded about 15% of a dioxan-insoluble residue, the analysis of which (C, 43.4; H, 6.4; OCH_3, 4.7; xylan, 72.2; ash, 4.7%) indicates that it originated from the xylan of the wood, eucalyptus woods being rich in this fraction. The yield of crude product amounted to about 21% of the wood, while the yield of carbohydrate-free lignin was about 18% of the wood. From the filtered dioxan solution, using the technique of Marshall, Brauns, and Hibbert (*4*), the main reaction product, alkali lignin-A, may be obtained by pouring into a large excess of ether and purified by repeated reprecipitation of its dioxan solution into ether.

Eucalyptus regnans alkali lignin-A is a fine powder, light brown in color, has no sharp melting point but commences to soften at 183°C. It is soluble in pyridine, dioxan, glacial acetic acid, and aqueous sodium hydroxide; is slightly soluble in ethanol and acetone; and is insoluble in ether, light petroleum, benzene, chloroform, ethyl acetate, water, and aqueous sodium bicarbonate. It is precipitated from its alkaline solution at pH 4.1, and potentiometric titration gives a curve with two points of inflection. From the main point of inflection at pH 7.6 the equivalent weight was calculated to be 670.

Table I. ***Eucalyptus regnans*** **Alkali Lignin-A**

No.	Compound	Empirical formula	Constituent groups: OCH_3	OH	Acyl		C, %	H, %	N, %	OCH_3, %	$COCH_3$, %	(C)CH_3, %
1	Alkali lignin-A	$C_{68}H_{78}O_{27}$ = 1327	9	7	0	f	61.5	6.0	...	20.9	...	1.1
						c	61.6	5.9	...	21.1	...	1.1
2	1 + CH_2N_2	$C_{71}H_{84}O_{27}$ = 1369	12	4	0	f	62.7	6.2	...	27.7	...	...
						c	62.3	6.2	...	27.2	...	...
3	1 + Ac_2O	$C_{82}H_{92}O_{34}$ = 1622	9	0	7	f	61.0	5.7	...	17.6	18.3	...
						c	60.7	5.7	...	17.2	18.5	...
4	2 + Ac_2O	$C_{79}H_{92}O_{31}$ = 1538	12	0	4	f	61.8	6.2	...	24.5	11.2	...
						c	61.7	6.0	...	24.2	11.2	...
5	1 + BzCl in C_5H_5N	$C_{117}H_{106}O_{34}$ = 2056	9	0	7	f	68.4	5.2	...	13.3	...	...
						c	68.4	5.2	...	13.6	...	...
6	1 + BzCl in NaOH	$C_{110}H_{102}O_{33}$ = 1952	9	1	6	f	67.6	5.4	...	14.4	...	...
						c	67.7	5.3	...	14.3	...	...
7	1 + Ph·NH·NH_2	$C_{80}H_{88}O_{25}N_4$ = 1506	9	...	...	f	64.0	5.7	3.7	18.6	...	...
						c	63.9	5.9	3.7	18.6	...	...
8	1 + *p*-NO_2·C_6H_4·NH·NH_2	$C_{74}H_{83}O_{28}N_3$ = 1462	9	...	...	f	60.8	5.7	3.1	19.2	...	...
						c	60.7	5.7	2.9	19.1	...	...
9	1 + *m*-NO_2·C_6H_4·CHO	$C_{75}H_{81}O_{29}N$ = 1460	9	...	...	f	62.0	5.5	1.0	19.1	...	...
						c	61.8	5.6	1.0	19.1	...	...
						f	64.1	5.9	...	19.4	...	...
10	1 + Ph·CHO	$C_{75}H_{82}O_{27}$ = 1415	9	...	...	c	63.7	5.8	...	19.7	...	...

In Table I are given the analyses of this particular alkali lignin-A and of nine of its derivatives. It is seen that it reacts with *p*-nitrophenylhydrazine to give a hydrazone with 3.1% nitrogen, and with *m*-nitrobenzaldehyde to give a product with 1.0% nitrogen. A rough approximation for the minimum molecular weight of these condensation products may be calculated from their nitrogen contents and these values (1360 and 1400, respectively) are in reasonable agreement with the value obtained by doubling the equivalent weight (1340). On the assumption that the molecular weight is of this order, the empirical formula of $C_{68}H_{78}O_{27}$ (1327) with nine methoxyl groups was tentatively selected as that which agrees best with the data, and in

Table II. ***Eucalyptus regnans*** **Ethanol Lignin-A**

No.	Compound	Empirical formula	Constituent groups: OC_2H_5	OCH_3	OH	Acyl		C, %	H, %	N, %	OR, %	OCH_3, %	$COCH_3$, %
1	Ethanol lignin-A	$C_{72}H_{82}O_{28}$ = 1395	2	9	7	0	f	62.3	5.9	...	24.6	20.0	...
							c	62.1	5.9	...	24.5	20.0	...
2	No. 1 + CH_2N_2	$C_{74}H_{86}O_{28}$ = 1423	2	11	5	0	f	62.5	6.2	...	28.3	23.8	...
							c	62.5	6.1	...	28.3	24.0	...
3	No. 1 + Ac_2O	$C_{86}H_{96}O_{35}$ = 1690	2	9	0	7	f	61.3	5.7	...	20.3	16.5	18.0
							c	61.3	5.7	...	20.2	16.5	17.8
4	No. 2 + Ac_2O	$C_{84}H_{96}O_{33}$ = 1633	2	11	0	5	f	62.0	5.8	...	24.6	21.0	13.5
							c	61.7	5.9	...	24.7	20.9	13.2
5	No. 1 + BzCl in C_5H_5N	$C_{121}H_{110}O_{35}$ = 2124	2	9	0	7	f	68.4	5.3	...	16.2	13.1	...
							c	68.4	5.2	...	16.1	13.1	...
6	No. 1 + BzCl in NaOH	$C_{187}H_{102}O_{33}$ = 1916	2	9	2	5	f	67.0	5.4	...	17.5	15.2	...
							c	67.1	5.4	...	17.8	14.6	...
7	No. 2 + BzCl in C_5H_5N	$C_{109}H_{106}O_{33}$ = 1944	2	11	0	5	f	65.8	5.5	...	20.6	17.8	...
							c	67.3	5.5	...	20.7	17.6	...
8	No. 2 + BzCl in NaOH	$C_{88}H_{94}O_{30}$ = 1632	2	11	3	2	f	64.8	5.8	...	25.1	20.9	...
							c	64.7	5.8	...	24.7	20.9	...
9	No. 1 + Ph·NH·NH_2	$C_{84}H_{94}O_{26}N_4$ = 1576	2	9	...	...	f	64.4	6.0	3.5	21.6	17.7	...
							c	64.1	6.0	3.6	21.7	17.7	...
10	No. 1 + *p*-NO_2·C_6H_4·NH·NH_2	$C_{84}H_{92}O_{30}N_6$ = 1666	2	9	...	...	f	60.6	5.6	5.1	20.5	16.8	...
							c	60.6	5.6	5.1	20.5	16.8	...
11	No. 1 + *m*-NO_2·C_6H_4·CHO	$C_{79}H_{85}O_{30}N$ = 1529	2	9	...	...	f	62.4	5.7	0.9	22.5	18.6	...
							c	62.2	5.6	0.9	22.3	18.3	...

Table I the theoretical values calculated on this basis are shown for comparison with the values obtained.

It is seen that, on the basis of nine methoxyl groups, the molecule contains seven hydroxyl groups. Of these, three are sufficiently acidic to react with diazomethane, the four that do not react with this reagent still remaining free to react when the methylated alkali lignin-A is acetylated. Of the four alcoholic hydroxyl groups, one is presumably tertiary or in some other way sterically hindered, as a Schotten-Baumann benzoxylation yields only a hexabenzoate compared with the heptabenzoate and hepta-acetate resulting from acylation in pyridine. The reaction with *p*-nitrophenylhydrazine indicates the presence in the molecule of a carbonyl group, while the reaction with phenylhydrazine itself yields a product whose analysis is best interpreted as an osazone. Finally, the presence of an active methylene group is indicated by the formation of condensation products with benzaldehyde and *m*-nitrobenzaldehyde.

Table III. Partial De-ethylation of *Eucalyptus regnans* Ethanol Lignin-A

	C %,	*H*, %	*OR*, %	OCH_3 %
Alkaline hydrolysis	60.6	5.8	22.8	20.5
Acid hydrolysis	60.9	5.6	22.3	20.7
Calc. for $C_{70}H_{80}O_{29}$ (1385)	60.7	5.8	22.4	20.2

ETHANOL LIGNIN (5)

When *Eucalyptus regnans* wood meal was refluxed for 48 hr. with 2% ethanolic hydrogen chloride, a yield of 18% crude ethanol-soluble ethanol lignin was obtained. This contained a trace of xylan, which was eliminated by purification from acetone-water. On applying the fractionation procedure described above, viz., repeated precipitation of a 10% dioxan solution into ether, the main product, ether-insoluble ethanol lignin-A was obtained in a yield of 50% of the crude product. *E. regnans* ethanol lignin-A is a light brown powder softening at 198°C.; is soluble in ethanol, acetone, chloroform, acetic acid, ethyl acetate, dioxan, pyridine, and aqueous alkalies; and is insoluble in ether, light petroleum, benzene, water, and aqueous sodium bicarbonate. Potentiometric titration indicates an equivalent weight of 1410.

The alkoxyl content of *E. regnans* ethanol lignin-A is 24.6% calculated as methoxyl, of which 20.0% is methoxyl. Hence, the ratio of methoxyl groups to ethoxyl groups is 4.3 to 1. Now, if the equivalent weight is 1410, the minimum molecular weight must be of this order, which would correspond to a molecule containing two ethoxyl and nine methoxyl groups, the empirical formula $C_{72}H_{82}O_{28}$ agreeing best with the data.

In Table II are set out the analyses of *E. regnans* ethanol lignin-A and ten of its derivatives. It is seen that, on the basis of nine methoxyl groups, there are present in the molecule seven hydroxyl groups as in alkali lignin-A. But, of these seven hydroxyl groups, only two react with diazomethane, compared with three in alkali lignin-A. Furthermore, whereas alkali lignin-A yielded a heptabenzoate with benzoyl chloride in pyridine and a hexabenzoate by a Schotten-Baumann reaction, ethanol lignin-A yields a heptabenzoate in pyridine but only a pentabenzoate in aqueous alkali. Another point of interest was found regarding the alcoholic hydroxyl groups of ethanol lignin-A. When ethanol lignin-A was methylated with diazomethane it yielded a dimethyl derivative which should still contain five free hydroxyl groups. That this is the case is shown by the formation of a penta-acetate. And as Schotten-Baumann benzoylation of ethanol lignin-A yields a product with two hydroxyl groups still free, it would be expected that Schotten-Baumann benzoylation of the dimethyl derivative would yield a tribenzoate. This, however, is not the case, the product being a dibenzoate. One of the alcoholic hydroxyl groups is apparently hindered by methylation from subsequent reaction with benzoyl chloride in aqueous alkali.

It was found that alkali lignin-A contained a carbonyl group, *p*-nitrophenylhydrazine yielding a mono-*p*-nitrophenylhydrazone. In contrast to this ethanol lignin-A yields a bis-*p*-nitrophenylhydrazone and thus contains two carbonyl groups in the molecule.

Table IV. Complete De-ethylation of *Eucalyptus regnans* Ethanol Lignin-A

No.	*Compound*	*Empirical formula*	*Constituent groups* OCH_3	*OH*	*Acyl*		*C*, %	*H*, %	*N*, %	OCH_3 %[a]	OCH_3 %[b]	$COCH_3$ %
1	De-ethylated ethanol lignin-A	$C_{68}H_{74}O_{28}$ = 1339	9	9	0	f	61.3	5.5	...	20.7	20.8	...
						c	61.0	5.6	...	20.9		...
2	1 + CH_2N_2	$C_{71}H_{80}O_{28}$ = 1381	12	6	0	f	61.9	5.7	...	27.1	27.0	...
						c	61.7	5.8	...	27.0		...
3	1 + Ac_2O	$C_{82}H_{88}O_{35}$ = 1634	9	2	7	f	60.4	5.5	...	17.5	17.1	19.0
						c	60.3	5.4	...	17.1		18.5
4	1 + BzCl	$C_{131}H_{110}O_{37}$ = 2276	9	0	9	f	69.2	4.8	...	12.5	...	...
						c	69.1	4.9	...	12.3	...	...
5	1 + Ph·NH·NH_2	$C_{74}H_{80}O_{27}N_2$ = 1429	9	...	...	f	62.8	5.6	2.2	19.7	...	...
						c	62.2	5.6	2.0	19.6	...	...
6	1 + *p*-NO_2·C_6H_4·NH·NH_2	$C_{74}H_{79}O_{29}N_3$ = 1474	9	...	...	f	60.1	5.4	2.9	18.8	...	...
						c	60.3	5.4	2.9	19.0	...	...

[a] Total alkoxyl by the method of Viebock and Brecher.
[b] Methoxyl by the method of Willstätter and Utzinger.

HYDROLYSIS OF ETHANOL LIGNIN-A (6)

The nature of the reaction involved in the alcoholysis of protolignin is not yet fully understood and there are contradictions in the literature. With the exception of Friedrich, all workers who have investigated the hydrolysis of alcohol lignins have reported that they are stable to alkali but decomposed by acid, and on these grounds many believe that alcohol lignins are acetals. On the other hand, Friedrich (7) reported that, of the two additional methoxyl groups formed by methanolysis, one was hydrolyzed by alkali and hence was presumably an ester. In view of these contradictions the stability of *E. regnans* ethanol lignin-A to both acid and alkaline hydrolysis was investigated, and it was

found that the two ethoxyl groups present differed in their ease of hydrolysis. With cold 10% sodium hydroxide one ethoxyl group is split off to yield a partially de-ethylated product. With boiling 10% hydrochloric acid the same thing occurs, the two partially de-ethylated products having the same analysis (Table III). The analysis suggests that a second molecule of water has been taken up according to the equations:

$$C_{72}H_{92}O_{28} + H_2O = C_{70}H_{78}O_{28} + C_2H_5OH$$

$$C_{70}H_{78}O_{28} + H_2O = C_{70}H_{80}O_{29}$$

These facts support Friedrich's findings, and are certainly evidence against the acetal theory for it is extremely unlikely that the two alkoxyl groups of an acetal would differ in their ease of hydrolysis.

Table V. Alkaline Hydrolysis of *Eucalyptus regnans* Ethanol Alkali Lignin-A

	Compound	*C, %*	*H, %*	*OR, %*	*OCH_3, %*	*(C)CH_3, %*
1	Alkali lignin-A	61.7	5.8	21.7	...	1.1
2	Ethanol alkali lignin-A	63.3	5.9	24.0	21.6	2.3
3	Alkali hydrolyzed ethanol alkali lignin-A	61.5	5.7	21.6	...	1.6

With the object of hydrolyzing both ethoxyl groups, both ethanol lignin-A and the partially de-ethylated product were distilled with hydrochloric acid, i.e., the concentration was gradually increased. This yielded a completely de-ethylated product whose analysis agreed with the empirical formula $C_{68}H_{74}O_{28}$ corresponding to the equation:

$$C_{72}H_{82}O_{28} + 2H_2O = C_{68}H_{74}O_{28} + 2C_2H_5OH$$

for the hydrolysis. In Table IV are shown the analyses of this de-ethylated product and five derivatives, and it is seen that this drastic acid treatment has brought about changes other than the simple hydrolysis of two ethoxyl groups. For example, whereas ethanol lignin-A had two carbonyl groups, the de-ethylated product has only one.

Although acetylation only yielded a hepta-acetate, benzoylation yielded a nonabenzoate, indicating the presence of two hydroxyl groups more than in ethanol lignin-A. Similarly, while diazomethane methylation of ethanol lignin-A yielded a dimethyl derivative, a trimethyl derivative is formed from the de-ethylated product, indicating that one of the new hydroxyl groups is acidic. This is supported by the fact that one of the ethoxyl groups of ethanol lignin-A is unstable to alkaline hydrolysis.

ETHANOL ALKALI LIGNIN (*8*)

It was unfortunately not possible to carry out the ethanolysis of alkali lignin on the sample described above. A preliminary ethanolysis of it yielded products whose analyses were difficult to interpret, and a check analysis of the alkali lignin-A showed that it had undergone some chemical change during the 3 years that had elapsed since its isolation (found in 1948: C, 61.5; H, 6.0; OCH_3, 20.9%; found in 1951: C, 59.5; H, 5.7; OCH_3, 19.8%). The sample used was obtained from the same wood, which was pulped under the same conditions, but the black liquor was acidified with carbon dioxide instead of sulphuric acid. This yielded a lignin acid salt which, after acidification and fractionation from dioxan-ether yielded an alkali lignin-A with the slightly higher methoxyl content of 21.7%, compared with the 20.9% previously obtained.

When this alkali lignin-A was refluxed with 0.5% ethanolic hydrogen chloride, the main reaction product was the dioxan-ether insoluble ethanol alkali lignin-A. This contained 24.0% alkoxyl, expressed as methoxyl, of which 21.6% was present as methoxyl, corresponding to a methoxyl: ethoxyl ratio of nine to one, and an empirical formula of $C_{68}H_{76}O_{25}$.

Now the analysis of the alkali lignin-A used corresponded to an empirical formula of $C_{66}H_{74}O_{26}$ with nine methoxyl groups. Hence ethanolysis of alkali lignin-A appears to have involved the ethylation of one hydroxyl group accompanied by the elimination of a second molecule of water:

$$C_{66}H_{74}O_{26} + C_2H_5OH = C_{68}H_{78}O_{26} + H_2O$$

$$C_{68}H_{78}O_{26} = C_{68}H_{76}O_{25} + H_2O$$

It was shown above that when ethanol lignin-A is subjected to a mild alkaline hydrolysis one of the ethoxyl groups is hydrolyzed and a molecule of water is

Table VI. *Eucalyptus regnans* Ethanol Alkali Lignin-A

No.	*Compound*	*Empirical formula*	*Constituent groups* *OEt*	*OMe*	*OH*	*Acyl*		*C, %*	*H, %*	*N, %*	*OR, %*	*OCH_3, %*	*$COCH_3$, %*	*(C)CH_3, %*
1	Ethanol alkali lignin-A	$C_{68}H_{76}O_{25}$ = 1293	1	9	6	0	f	63.3	5.9	...	24.0	21.6	...	2.3
							c	63.2	5.9	...	24.0	21.6	...	2.3
2	1 + CH_2N_2	$C_{68}H_{78}O_{25}$ = 1307	1	10	5	0	f	63.1	6.0	...	26.6	23.8	...	2.4
							c	63.4	6.0	...	26.1	23.7	...	2.3
3	1 + Ac_2O	$C_{80}H_{88}O_{31}$ = 1546	1	9	0	6	f	63.0	5.7	...	19.8	17.7	16.0	...
							c	62.2	5.7	...	20.1	18.1	16.7	...
4	1 + BzCl in C_5H_5N	$C_{110}H_{100}O_{31}$ = 1918	1	9	0	6	f	69.3	5.3	...	16.0	14.0	...	...
							c	68.9	5.3	...	16.2	14.6	...	...
5	1 + BzCl in NaOH	$C_{103}H_{96}O_{30}$ = 1814	1	9	1	5	f	68.5	5.1	...	16.8	15.1	...	...
							c	68.2	5.3	..	17.1	15.4	...	...
6	2 + Ac_2O	$C_{75}H_{84}O_{28}$ = 1434	1	10	2	3	f	63.4	6.0	...	23.3	21.3	9.1	...
							c	62.8	5.9	...	23.8	21.6	9.0	...
7	2 + BzCl in C_5H_5N	$C_{76}H_{82}O_{26}$ = 1412	1	10	4	1	f	63.9	6.1	...	24.1	22.2	...	..
							c	64.6	5.9	...	24.2	22.0	..	..
8	1 + Ph·NH·NH_2	$C_{74}H_{82}O_{24}N_2$ = 1383	1	9	...	...	f	63.8	6.0	1.5	22.3	19.1	...	...
							c	64.3	6.0	2.0	22.4	20.2	..	..
9	1 + *p*-NO_2·C_6H_4·NH·NH_2	$C_{74}H_{81}O_{26}N_3$ = 1428	1	9	...	..	f	62.4	5.7	2.5	22.1	19.0	...	..
							c	62.2	5.7	2.9	21.7	19.6	...	.

taken up. When these conditions are applied to ethanol alkali lignin-A the same reaction takes place. The ethoxyl group is hydrolyzed and a molecule of water taken up to yield a product with the same analysis as the original alkali lignin-A (Table V). Hence the formation of ethanol alkali lignin-A appears to involve the ethylation of an acidic hydroxyl group.

A series of derivatives was made and the analyses of these are given in Table VI. From a consideration of these data several interesting points emerge. First, as alkali lignin-A contained seven hydroxyl groups, and as ethanolysis involves the ethylation of one of these, we would expect ethanol alkali lignin-A to contain six hydroxyl groups. This is shown to be correct, acetylation and benzoylation yielding the expected hexaacetate and hexabenzoate. Similarly, Schotten-Baumann benzoylation yields a hexabenzoate from alkali lignin-A and a pentabenzoate from ethanol alkali lignin-A.

Of the seven hydroxyl groups of alkali lignin-A three are acidic. Diazomethane converts alkali lignin-A to a trimethyl derivative which in turn yields a tetraacetate. Since one of these is ethylated during the formation of ethanol alkali lignin-A, we would expect the latter to yield a dimethyl derivative with four free hydroxyl groups. However this does not happen; diazomethane methylates only one hydroxyl group and the product yields only a triacetate. It appears that ethanolysis has not only ethylated an acidic hydroxyl group, but in so doing has brought about some change in the reactivity of another acidic hydroxyl group and one of the alcoholic hydroxyl groups. Although they are still present, as evidenced by the formation of the hexaacetate and hexabenzoate, one acidic hydroxyl is no longer capable of reacting with diazomethane, and methylation of the remaining acidic hydroxyl prevents one of the alcoholic hydroxyl groups from being acetylated. In view of the fact that, of the three alcoholic hydroxyls that react with acetic anhydride, only one is capable of being benzoylated, steric hinderance may be a factor.

One other point to be noted concerns the reaction with phenylhydrazines. From the reaction with *p*-nitrophenylhydrazine it is apparent that there is only one carbonyl group present in both alkali lignin-A and ethanol alkali lignin-A. And, while ethanol alkali lignin-A reacts with phenylhydrazine to yield the corresponding phenylhydrazone, alkali lignin-A yields an osazone. It is possible that the alcoholic hydroxyl group whose reactivity is affected when alkali lignin-A is ethanolyzed and subsequently treated with diazomethane, is a secondary alcoholic group adjacent to the carbonyl group, and in ethanol alkali lignin-A is no longer capable of entering into osazone formation.

PROTOLIGNIN

In the light of the evidence that ethanol alkali lignin-A contains only one ethoxyl group, and that readily saponified by alkali, it is obvious that ethanol alkali lignin-A is not an acetal and that the ethoxyl is present either as an ester or as the ether of an acidic hydroxyl group. This suggests that the ethoxyl groups of ethanol lignin-A are likewise not in the form of an acetal, but rather as ester or ether, a suggestion which is further supported by the fact that the two ethoxyl groups differ in their ease of hydrolysis, one being readily saponified by dilute acid or alkali while the other is stable to these reagents. From this it may be deduced that, as ethanol lignin-A contains seven hydroxyl and two ethoxyl groups, protolignin contains nine hydroxyl groups, two of which need not necessarily be free but may be combined with some other wood component.

From the fact that one of the ethoxyl groups of ethanol lignin-A is hydrolyzed by alkali, it may be inferred that one of these additional hydroxyl groups is acidic. Hence, as ethanol lignin-A contains two acidic and five alcoholic hydroxyl groups, we may deduce that protolignin contains three acidic and six alcoholic hydroxyl groups. This is supported by the fact that, of the nine hydroxyl groups in de-ethylated ethanol lignin-A, three were acidic. It may also be inferred that, on the assumption that carbonyl groups are not involved in ethanolysis, the two carbonyl groups of ethanol lignin-A are present in protolignin.

Alkali lignin-A has been found to contain three acidic, four alcoholic hydroxyl groups, and one carbonyl group. Therefore, if the above assumptions are valid, alkaline pulping has resulted in the elimination of two alcoholic hydroxyl groups and one carbonyl group. Changes brought about by alkaline pulping other than these cannot be detected from the data. If it is assumed that ethanol lignin-A is merely an ethylated protolignin, and that ethanol lignin-A is represented by the empirical formula $C_{59}H_{38}O_{10}(OEt)_2(OMe)_9(OH)_7$, then protolignin would be represented by the empirical formula $C_{59}H_{38}O_{10}(OMe)_9(OH)_9$. For alkali lignin-A the data agree with the empirical formula $C_{59}H_{44}O_{11}(OMe)_9(OH)_7$, and little can be deduced from this.

Previous workers in this field—e.g., Brauns and Grimes (*2*)—using spruce as the raw material have noted that alkali lignin contains more acidic hydroxyl groups than does methanol lignin and have suggested that additional acidic hydroxyl groups are formed during alkaline pulping. Using *E. regnans* it has likewise been found that the ratio of acidic hydroxyl to methoxyl groups is higher for alkali lignin than for ethanol lignin, but the evidence suggests that this is due, not to the formation of new acidic hydroxyl groups during alkaline pulping, but rather to the etherification of existing acidic hydroxyl groups during ethanolysis. It has yet to be shown whether these groups are free in protolignin, or whether they are chemically combined in, perhaps, glycosidic union with carbohydrate.

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Fundamentals of the Paper Machine

A Symposium Sponsored Jointly by the Fundamental Research Committees of TAPPI and CPPA (Technical Section)

The Institute of Paper Chemistry, Appleton, Wis.
September 21–24, 1954

THE following papers and discussions provided the program for the Symposium on the Fundamentals of the Paper Machine held under the sponsorship of the TAPPI and CPPA (Technical Section) Fundamental Research Committees at The Institute of Paper Chemistry, Sept. 21–24, 1954.

A number of conferences have been held in recent years leading up to this meeting on the paper machine. These all had an international flavor, with speakers and audience from around the world. In 1947 the TAPPI Fundamental Research Committee sponsored a symposium in Appleton on the nature of the chemical components of wood. This was followed by a symposium at the Forest Products Laboratory in Madison directed toward the physical properties of those wood components. In May, 1950, the committees of the CPPA and TAPPI sponsored their first joint symposium in Quebec on the effect of fiber characteristics on paper and papermaking properties. In 1951, following the 75th Anniversary Meeting of the American Chemical Society and the XIIth International Congress of Pure and Applied Chemistry, both held in New York, the Fundamental Research Committee of TAPPI, in joint sponsorship with one of the National Research Council committees, put on an International Pulp and Paper Symposium with papers by scientists from Sweden, Japan, Norway, Great Britain, Germany, Australia, Canada, and the United States. The papers making up this symposium were basic in nature and of interest both to the pulp- and papermaker. In 1953 the series of international meetings switched from North America to Sweden with a symposium on the chemistry of wood and wood constituents held as a part of the XIIIth Congress of Pure and Applied Chemistry at Stockholm. Speakers and audience gathered in Stockholm from literally all over the world.

The two Fundamental Research Committees are happy to present this second meeting in their series and express the hope that it will provide another chapter in the joint effort to give to those concerned with the applications of the pulp and paper industry a better understanding of the underlying phenomena of the industry.

A word of explanation on the mechanics of the symposium may serve to give the reader a clearer picture of the objective of the meeting. Better than 3 years ago the respective Fundamental Research Committees began to ask themselves what were the distinguishable phenomena of greatest importance in the fundamental behavior of a paper machine? A large number suggested themselves; these were narrowed down to 15 or 20 general areas. Next the committees asked themselves and others who were the authorities in these fields, and from the names suggested a tentative list of speakers was built up. Invitations were sent out to these people about a year ago, and with only one exception they were accepted.

It was decided early in the planning that the day's papers would be limited to four each and the decision was kept fairly well, having four on each of two days and five on the other two. The papers were to be 45 min. in length and discussion was to be reserved until 3:00 p.m. each day when a panel made up of the day's speakers and discussion leaders for each paper, together with the chairman of the day as moderator, would handle questions put in question boxes by members of the symposium, questions directly from the floor, or questions from the discussion leaders themselves. The discussions were taken by a pair of stenotype operators working on short shifts. One day's discussion was thus available for correction the following morning. In this way, it was possible to provide corrected discussion copy for inclusion in *Tappi* and in the *Pulp and Paper Magazine of Canada* at the time of the printing of the papers. An important factor which helped the discussion was the advance preprinting of 16 of the 18 papers and the mailing of these to the symposium members well in advance of the meeting. Copies of the other two papers were on hand at the opening of the meeting. Members of the symposium were enthusiastic in their support of this procedure which resulted in many more questions being turned in than could possibly be answered in the daily 3 to 5:30 p.m. period. It is the hope of the two committees that the publication of papers and discussions will stimulate thinking and further research and will aid in a better understanding of the fundamentals of the paper machine.

In conclusion, the members of the two Fundamental Research Committees thank again and publicly, speakers, discussion leaders, session chairmen and all those participating in the question periods for their part in making this a worth-while meeting. Thanks are extended to the various companies for sending top technical personnel to the symposium and finally to The Institute of Paper Chemistry which provided facilities and services.

Introduction to the Symposium prepared by HARRY F. LEWIS, Chairman, TAPPI Fundamental Research Committee, and Dean, The Institute of Paper Chemistry, Appleton, Wis.

Flow in Fiber Suspensions and the Effects of Turbulence

J. A. VAN DEN AKKER

Because of the strong bearing of theory and observational phenomena of aero- and hydrodynamics on the flow of low-consistency fiber suspensions, the nature of the flow of fluids around bodies and through ducts is reviewed. Special attention is given to the way in which turbulence is generated in boundary layers and to the velocity distribution across a duct. The dependence of the "critical" Reynolds number on the nature of the system in which flow occurs is described. Reference is made to modern methods for characterizing and measuring turbulent motion. The probable effects of the presence of fiber on turbulence and of the effects of turbulence on fiber motion are discussed. Theory and numerical calculations are given to demonstrate that, in consideration of the motion of individual fibers viscous forces strongly predominate over inertial forces.

THE advantages of developing our knowledge on the flow of low-consistency fiber suspensions is so self-evident that we do not need to elaborate on them here. It is also obvious that we should cast out certain long-held but erroneous beliefs which have been retained only because they seemed reasonable and have been repeated by so many people over so many years. An excellent example is the dogma that, in a straight course of flowing pulp suspension, the fibers align, or tend to align, in the stream direction; nothing could be further from the truth in view of the observational fact that the distribution of the fibers, although not perfectly homogeneous, is isotropic in a streaming fiber suspension—even at such extraordinarily low consistencies as 0.0002% (about one fiber for every 5-mm. cube), where mechanical interaction between fibers is virtually nonexistent. It seems to be peculiarly true of the field of hydrodynamics that intuition can frequently lead to erroneous ideas; what is needed is insight based on observation and theory.

FLUIDITY OF LOW-CONSISTENCY FIBER SUSPENSIONS

The fiber-water system with which we are concerned in the present discussion has a consistency of the order of 0.5%. The population density is about 20 fiber centers per cubic millimeter. This means that the mechanical interactions between the fibers are not inappreciable, although Wollwage has shown that the force of adhesion between pulp fibers suspended in water is very small. Although frictional traction stress between a smooth metal surface and moving stock of several per cent consistency is a few pounds per square foot, it would appear from interpolation of data for water and Baldwin's data for stock of various consistencies that the frictional stress for 0.5% consistency fiber suspension is of the same order of magnitude as that for water. For a velocity of 4.1 ft. per sec., the former is about 0.1 lb. per sq. ft., while the latter is approximately 0.06 lb. per sq. ft. We may add the well-known fact that the simple Torricelli formula gives, with fair accuracy, the velocity of efflux of the fiber suspension from the slice, and conclude that the fluidity of the suspension in the headbox is very much closer to that of plain water than it is to that of stock in beaters and paper stock pipe lines. We are not about to conclude that we may regard the phenomena of flow of low-consistency fiber suspensions as being the same as those of the flow of water, because we feel sure that the presence of the fiber will modify such factors as the scale and intensity of turbulence. It is obvious, however, that the great field of theoretical and experimental work in aero- and hydrodynamics should provide a good basis for our thinking—of course, it already has been the basis for a number of investigations in the paper industry, probably most of which have never been published.

FLOW OF AN IDEAL FLUID

Let us begin our discussion by imagining an unbounded ideal fluid—that is, an incompressible fluid having no viscosity—moving from left to right with speed v. Certain stationary bodies may be mounted in this fluid, so that the latter flows around and among the bodies in a manner somewhat like that depicted in Fig. 1. In regions where the streamlines are crowded, the local speed is high (such as at B and D). There the local pressure is low. At certain other points (such as at A and C) the velocity is zero and the pressure is higher than that in the free fluid at points remote from bodies by the amount, $\rho v^2/2$, where ρ is the mass density of the fluid. Generally, the flow is known as "potential flow"; the velocity is everywhere derivable from a potential function. The flow at all points is governed by the Euler equation (the singular is here used to denote vectorial representation) and the equation of continuity. At all points the vorticity is zero; curl $\mathbf{v}$ or rot $\mathbf{v}$ is zero; and the circulation $\Gamma = \oint \mathbf{v} \cdot d\mathbf{s}$ is zero in the free fluid. This hypothetical fluid slips around all surfaces with no friction. There is no turbulence, and vortex motion cannot be created if the initial stream is free of vorticity. The motion is said to be irrotational.

FLOW OF A REAL FLUID

Except in unusual situations where the pure number $L\rho v/\mu$ (the Reynolds number, involving a length L designating the size of a body or duct, the mass density ρ of the fluid, the speed v of the fluid or of the body, and the viscosity μ of the fluid) is adequately small, the flow of real fluids like air and water around bodies at speeds of ordinary interest is turbulent. The motion of water around a "streamlined" body like that shown in the upper left of Fig. 1 will be almost like the classical potential flow for all points excepting those quite near the surface of the body, and it is for this reason that

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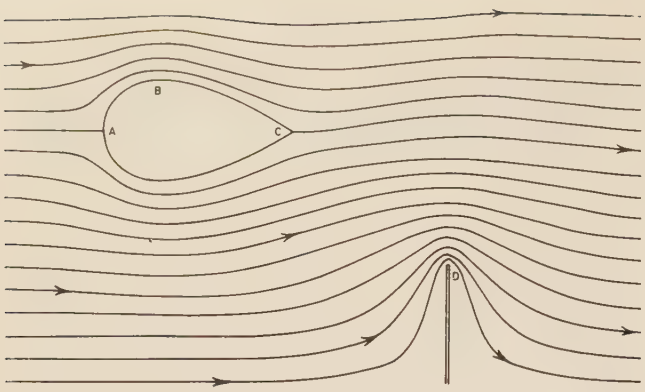

Fig. 1

skilled investigators in the fields of aero- and hydrodynamics have been able to employ solutions of the Euler equation to good advantage. However, turbulence is formed, and the manner of its forming, about which we shall speak later, is important to our present discussion. The flow around the upstream side of a bafflelike body will usually be pretty much like that shown in the lower right portion of Fig. 1, whereas the downstream volume of the fluid is filled with vortices; the wake is very turbulent. This seems to be a good place to recall a well-known and very useful generalization: convergence of streamlines has a stabilizing influence and eddies in the stream tend to be damped in a region of converging flow; the opposite condition exists in a region where the shape of a body or of a duct dictates a divergence of flow—it is difficult to decelerate a fluid without appreciably augmenting turbulent action, and increasing divergence results in an increasing degree of turbulence.

BOUNDARY LAYERS AND TURBULENCE

When water flows around a streamlined body like that in Fig. 1, the speed of flow falls off very rapidly near the wall (within perhaps a millimeter or less) and the velocity is zero at the wall. In the so-called laminar layer immediately in contact with the wall there is a substantial velocity gradient, or rate of shear and, in consequence, curl $\mathbf{v}$ or rot $\mathbf{v}$ is appreciable. In view of Stokes' theorem, there will also be a circulation $\Gamma = \oint \mathbf{v} \cdot d\mathbf{s}$ in this layer. Thus, we have a laminar layer in which there is vorticity, but no vortex motion or turbulence. But vorticity is a necessary (but not always sufficient) condition for the formation, somewhere in the fluid, of eddies and turbulence. A number of distinguished investigators, beginning with Helmholtz, have shown the connection between fluid friction and the creation of turbulence. At the surface there is an appreciable frictional stress equal to $\mu(\partial v/\partial n)$, where v is the velocity, and n is distance from the surface measured in the direction of the normal (this stress may be large even when the viscosity is small, as in the case of water, because of the greatness of the rate of shear). Prandtl and his associates at Göttingen, in a brilliant period of experimental and theoretical work, elucidated the origin of turbulence in this frictional stress in the boundary layer, principally on the back surfaces of bodies. Let us return to the flow of the *hypothetical ideal fluid* around the streamlined body in Fig. 1. The speed of a point in the fluid near A is is almost zero; as this point approaches B, the velocity approaches a maximum value (for the given streamline) and, in accordance with the Bernoulli equation, the pressure drops to a minimum value. The increase in kinetic energy has come at the expense of flow work. When this point in the ideal fluid reaches the stagnation region at C, the pressure increases, at the expense of kinetic energy; the pressure gradient has brought the fluid nearly to rest near C. When a *real fluid like water* flows around the body, volume elements in the fluid *just outside* the layer of high rate of shear undergo changes in velocity and pressure in a manner closely similar to that just described for the ideal fluid. Thus, at points near C but just *outside* of the layer, the pressure has increased from that near B almost to the theoretical value. *Inside* the layer, the frictional drag has accounted for some dissipation of the kinetic energy (it has aided the pressure gradient in decelerating the fluid) and, in consequence, the pressure gradient along the surface from B to C is *less* than that developed in the fluid just outside of the layer. However, pressure is transmitted transversely through the fluid with but little change, so that the transverse pressure differential which exists between points inside and outside the layer results in a *backflow* of the fluid along the surface of the body. This is illustrated in Fig. 2, in which the thickness of the layer of fluid is greatly exaggerated. This illustration includes the limiting streamline that divides the lines of normal movement from the backflow lines. Of course, this action could cause the onset of an eddy. If the backflow region grows in size, forcing the streamlines of normal direction of flow outward, the eddy becomes larger and larger, finally breaking away to form part of the turbulent wake. Then another eddy system builds up, breaks away, etc. The streak-trail photographs taken by Prandtl, Tietjens, and others at Göttingen show beautifully the initial condition of almost potential flow followed by build-up of the backflow and eddies. The second volume of Tietjens' books based on Prandtl's lecture notes, entitled "Applied Hydro- and Aeromechanics," contains many streak-trail photographs that should be of considerable interest to any one concerned with headbox design.

Turbulent wakes form in similar manner behind bodies of other shapes, such as oval and round rods. When the shape is such as to favor the formation of downstream turbulence (a cylinder, a strip with the plane normal to the stream, etc.) the larger part of the drag force is accounted for in the turbulence. The greater part of friction head loss in the turbulent flow of a fluid in a duct is related to the continuous processes of transfer of energy to the kinetic form in vortices and dissipation of the latter to heat through viscous action in the fluid.

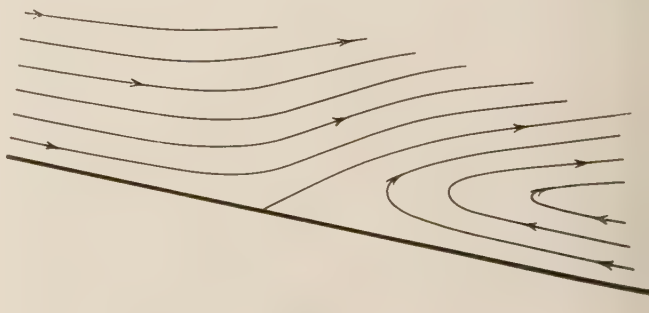

Fig. 2

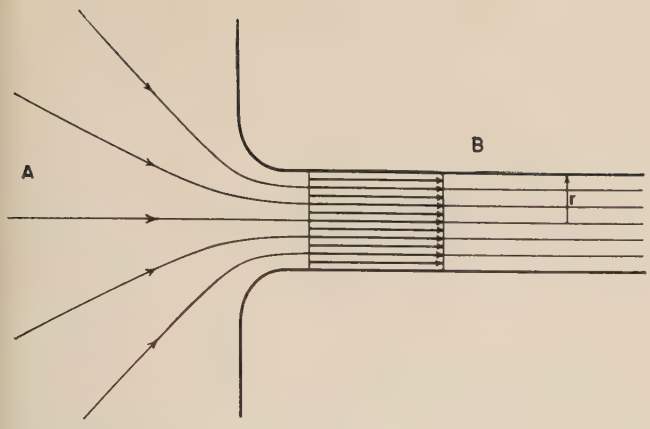

Fig. 3

Other considerations of importance to our discussion arise on studying the flow of gases and liquids in ducts. Let us consider the flow of a fluid from a quiescent sea at A in Fig. 3 into and through a circular pipe B of radius r. It is presumed that the pipe is perfectly straight, has a perfectly smooth wall, and is equipped with a rounded entrance shaped like a horn bell. If the Reynolds number $r\rho v/\mu$ is less than about 1000, flow in the tube will be nonturbulent or laminar, and the distribution of speed across the tube *far downstream from the entrance* will follow the familiar quadratic equation. The distribution of speed across the pipe near the entrance is *not* parabolic; whether the flow downstream is laminar or turbulent, the speed in the pipe near the entrance is nearly uniform. The speed falls off sharply near the wall, and is zero at the wall. If the flow is laminar, the Navier-Stokes equation governing the flow of a viscous fluid degenerates to a very simple form and we have the Poiseuille equation giving the pressure gradient required to overcome friction for all downstream points more remote from the entrance than $0.26\ (r\rho v/\mu)r$.

DEPENDENCE OF CRITICAL REYNOLDS NUMBER ON CONDITIONS OF FLOW

Now it does not follow (as is too commonly supposed) that turbulent flow must necessarily exist in the tube of Fig. 3 if the Reynolds number is greater than 1000 to 1100. A generalization from experiment is that, with increasing care in eliminating slight irregularities in the flow and temperature of the fluid from A (Fig. 3), and with increasing care in perfecting the design of the entrance bell, removing imperfections from the tube wall, etc., the velocity of flow and the Reynolds number can be increased to fantastically high values before turbulence sets in. This is obviously a special situation, the mention of which has value only in dispelling any "magic" about the number 1000 (or 2000 if the Reynolds number is expressed in terms of the pipe diameter). In any given situation the Reynolds number corresponding to the onset of turbulence in or near the entrance depends on the degree of turbulence of the entering fluid, the shape and smoothness of the rounded entrance (a sharp-edged entrance produces a *vena contracta* and favors the production of turbulence), and the smoothness of the inner tube surface. If a nonturbulent fluid flows into a rounded entrance, any turbulence that develops in the duct has its origin *in the boundary layer at the wall of the tube* and, in growing during downstream flow, produces irregularities of flow across the whole tube. It is worth noting that *the nature of the turbulence far downstream in the tube is primarily a function of the nature of the tube and the Reynolds number;* if the entering flow is almost free of turbulence, the turbulence will develop to a certain level and there maintain itself downstream; if, however, the entering fluid is highly turbulent, the degree and scale of the turbulence will gradually settle down (during flow downstream) to values characteristic of the pipe and the Reynolds number. Of course, the violence of turbulence increases with the Reynolds number.

Of special interest to us in this discussion is the influence of bodies in the stream (vanes, baffles, rods) on the value of the Reynolds number corresponding to the onset of turbulent motion. Here it seems desirable to emphasize that the critical Reynolds number is drastically influenced by the shape and orientation of a body. For example, the familiar Stokes' equation for the viscous drag on a sphere fails to be accurate when the Reynolds number (involving the radius of the sphere) is greater than about 0.5, and a vortex ring is formed when the Reynolds number is about 8. It is observed that an eddy pair forms behind a circular cylinder when the Reynolds number is only 3 and periodic separation of the eddies, forming a so-called Kármán trail, occurs when the Reynolds number is in the neighborhood of 100. If this leaves one with no feeling concerning the speed of water, for example, at which eddy separation occurs, we may consider a 1-in. circular rod mounted transversely in water flowing in a channel. The speed of the water corresponding to a Reynolds number of 100 is found to be only 0.026 ft. per sec. In the headbox of a high-speed fourdrinier paper machine the approach velocity (upstream from the slice a distance of a foot or so) is of the order of magnitude of 1 ft. per sec. Thus turbulence in headboxes produced by obstructions is to be expected—such turbulence is well known to engineers engaged in studies of headboxes.

CHARACTERIZATION OF TURBULENCE

The numerical characterization of turbulence has plagued specialists in the fields of aero- and hydrodynamics for years. The onset and nature of turbulence cannot be calculated from the Navier-Stokes equation (a general solution of which has never been found), although it is believed that this equation governs turbulence and all other aspects of the flow of a viscous fluid. The minds of men working in the field have developed quite naturally, the concepts of randomness of relative velocity fluctuations, linear size, or scale of the turbulence (of which the Prandtl mixing length is an example), and energy or intensity of turbulence. Starting with the work of Osborne Reynolds on the theory of turbulent flow, nearly 60 years ago, advanced mathematical methods have been evolved which have supplemented and guided the development of experimental measures of turbulence. The development of the theory has been crudely analogous to that of statistical mechanics; just as one assumes that, in a gas, the distribution functions for position and velocity components are uniform throughout the system, the modern theory of turbulence has been developed for so-called homogeneous turbulence, in which the characteristics of the turbulence are uniform

for all points across the stream. The turbulence is both homogeneous and isotropic if the distribution functions for the three relative velocity components are the same (which amounts to saying that there is as much eddying with axis parallel to the stream as there is with axes parallel to the other two principal directions). Theory and observation deal with the "joint probability distribution," which involves fluctuations of velocity components at separated points. The mathematical treatment is far too complex for condensation at this time. Batchelor has recently published a review article and a book; the former is recommended for technical men of usual training in mathematics, while the latter is useful primarily to mathematicians and to physicists and engineers having training and experience in advanced mathematics. An idea, however, of what is involved experimentally can be gained from the following.

Suppose that we place a pair of hot-wire anemometers in the stream of turbulent air in a wind tunnel. (Modern hot-wire anemometers and their associated electronic systems are designed to have very fast response.) If the hot wires are remote from each other, their indications of simultaneous velocity fluctuations will not correlate; obviously, if they are nearly in contact, they will sense the same fluctuations, and the latter should (in principle) correlate perfectly. One way of getting at the scale of the turbulence is to deal with a plot of the correlation coefficient versus separation distance. The root mean square of the velocity fluctuation at either anemometer serves as a measure of the intensity of the turbulence. Other means for characterizing turbulence involve determination of the energy spectrum and measurement at two separate points of simultaneous velocity difference, velocity products, and first and higher order differentials of velocity.

BOUNDARY LAYER AND VELOCITY DISTRIBUTION IN TURBULENT FLOW

As a wall of a duct is approached, one finds that both the scale and intensity of the turbulence are reduced. If the stream is studied at points sufficiently far downstream from the quiescent sea of Fig. 3 for the turbulence to be nearly homogeneous and steady (at points remote from the wall), it will be found that the velocity component in the direction of the stream (and parallel to the wall) fluctuates appreciably in the laminar boundary layer, at points very close to the wall (within thousandths of an inch). These fluctuations are, of course, attributable to turbulent shear in the adjacent turbulent boundary layer. In the thin laminar layer the *mean* velocity increases linearly with distance from the wall, and then the dependence of the mean velocity on distance falls strongly as the point of consideration passes through the turbulent boundary layer (in which the velocity varies as the seventh root of the distance). Between the laminar layers on the two sides of a duct the stream is filled with turbulence. In this turbulent zone the velocity exhibits little change across the duct. At a distance from the wall equal to only 2% of the duct radius the mean velocity is about 0.7 of the average for the whole tube, and at the center of the duct the ratio is about 1.25. Thus, the effect of turbulence on, for example, fiber motion is of considerably greater importance than a statistically averaged rate of shear ($\partial\bar{v}/\partial r$).

TURBULENCE IN A HEADBOX

If the flow in a headbox is from a pond or other volume of fiber suspension that is quiescent, the concept of homogeneous turbulence may not be applied. In his 1952 review article, Batchelor refers to the difficulty of ascertaining whether turbulence theory may be employed. The distance downstream that is required for the turbulence to become characteristic of the duct and of the velocity of flow (for a duct that is free of obstructions) is greater than the downstream dimension of most headboxes. It would be unimaginative to install self-cleaning bars, grids, perforated rolls, etc. in an experimental headbox merely so that theory could be applied (although such installation may prove to be desirable for other reasons). For the making of certain types of paper it may be desirable to experiment with headboxes in which there are no obstructions and in which the flow contains only low-intensity turbulence; in a situation like this, theory based on an equilibrium in the interchange of energy from large-scale to small-scale components of turbulence could scarcely apply, and one should not force an improper application of theory in his zeal to do the job in a "fundamental" manner. On the other hand, if turbulence in the headbox is desired, one would do well to generate the turbulence with modern turbulence theory in mind; one should hasten to add that design for experiment or production should be based on all hydrodynamical theory and observational phenomena!

If the need of the papermaker were that of obtaining uniform flow of turbulent or nonturbulent pure water from a slice, the problem would be difficult enough; but he needs uniform flow across the machine of a *fiber suspension* which, for definiteness, we have characterized as having a consistency of 0.5%. How does this complicate an already complicated array of flow phenomena? In the writer's opinion, the presence of the fiber does not substantially alter the phenomena which have been discussed. Reasoning from their data on the flow of 1% consistency paper stock in large pipes, Forrest and Grierson concluded that the presence of fiber in water suppresses turbulence (the friction head loss for stock at very low speeds of flow is very much higher than that for water, but the situation changes at higher speeds—where it is known that the nearly quadratic relation between head loss for water and velocity is due to turbulence—and the friction head loss for water is much greater than that for the paper stock). We know that turbulence is generated in the flow of low-consistency paper stock, and we suspect that the onset of turbulence in boundary layers and surfaces of confluence of streamlines operates with mechanisms that are the same as those observed for water. It would seem, then, that the primary effects of the fiber would be to lessen the intensity of turbulence and possibly also to shift the energy spectrum somewhat to a larger scale of turbulence.

The age-old effect of turbulence in a fiber suspension is the desirable one of dispersing the fibers. Although the phenomenon is analytically complicated, the mechanical understanding of what goes on is so simple to comprehend that we need not dwell upon it here

In the language of the statistical approach, a "random walk" is involved; in a turbulent field, in which relative velocities are random, two points, now in close proximity will, on the average, later be separated by a greater distance. However, turbulence of very low intensity serves kinetically to bring fibers together, and if the forces arising in local relative velocities are insufficient to overcome the low-order forces of contact between fibers in an agglomerate, flocculation of the fibers will occur. Therefore, it is only a rule that turbulence will disperse fibers—not a generalization.

The tendency of fibers to "staple over" or be caught by grids, rods, stirrers, and other devices which have been tried in headboxes is a stumbling block to developmental work. For this reason the hot-wire anemometer may not be employed for the measurement of mean velocity and turbulence characteristics. It is possible that self-clearing Pitot tubes could be used with modern, sensitive pressure transducers operated in connection with suitable electronic gear. Work in this direction is urged in view of another stumbling block: optical studies of the flow and turbulence in the body of the suspension, away from walls, is practically impossible because of the opacity of a 0.5% consistency slurry. (It is possible that some progress could be made by using slurries of bleached pulp in a liquid whose index of refraction closely matches the average index of cellulose and whose viscosity and density are not greatly different from those of water. Then, with a very small fraction of the fibers tagged with dye, microflash pictures similar to those taken by Bryant and Moss might successfully be made at small distances from the transparent wall facing the camera. A further specification for the liquid, to be added if preliminary experiments were encouraging, is that the flocculating and frictional effects of the suspended fibers should be comparable to those observed when water is the medium.)

POSSIBLE INFLUENCE OF TURBULENCE ON EFFLUX VELOCITY

One of the most important goals in the design of a headbox-slice system is uniformity of efflux velocity across the machine. It is for this reason that one or more perforated rolls is to be found in many headboxes. The action is essentially the same as that of the stilling racks, honeycombs, grids, and gauzes employed in wind tunnels and water channels to even the flow and damp large-scale eddies. Of course, the passage of the fiber suspension through the openings of these rolls produces moderately small-scale turbulence, which may not be optimum with regard to the several desirable and undesirable effects of turbulence. It is known, for example, that converging flow (of the sort that occurs at the slice) damps eddies, and it is believed that the reduction of the energy of eddies depends upon the orientation of their axes of rotation with respect to the stream direction. If the turbulence in the stream flowing under the slice is not homogeneous and if the anisotropy of the turbulence across the machine is variable, it is reasonable to expect that these departures from uniformity of turbulence will cause variability of efflux velocity across the machine. In other words, perhaps more attention should be paid to the influence of variability of small-scale turbulence on the apparent hydrodynamic resistance to flow under the slice. Much attention has been paid to variability of streaming velocity or approach velocity in the headbox as a source of nonuniform efflux velocity. It is not the intention here to reject the influence of variable approach velocity; but, in consideration of the fact that the "approach velocity head" ($v^2/2g$) varies with the square of the velocity and that the squares of small numbers are quite small, may we attribute across-machine variability of efflux velocity largely to variability of streaming in the headbox? Possibly more work should be done on the relationship between the apparent hydraulic resistance of the slice and the measured characteristics of the turbulence in the fiber suspension just upstream from the slice opening.

In any event, where turbulence is desired it would be of interest to explore the advantages of increasing the homogeneity of turbulence (through study of turbulence generators) and increasing somewhat the distance between the last turbulence generator and the slice; the latter factor would tend to render the turbulence more isotropic as well as more homogeneous. With regard to isotropy, it is an interesting fact of observation that turbulence, even though anisotropic at the point of generation, becomes almost isotropic at a distance downstream equal to several times the diameter or spacing of the openings in the generator.

ERRATIC TURBULENCE

In an apparatus or equipment designed to minimize turbulence, such as a headbox without sharp bends, baffles, vanes, or perforated rolls, one should be sure that the turbulence generated at the walls of the supply duct and of the headbox is not erratic. It is well known that certain hydraulic systems will exhibit periodic spouting and this effect, when present in only a small degree in a headbox-slice system, might well lower the quality of the paper that is made.

DOMINANCE OF VISCOUS FORCES IN MOTION OF FIBERS

Before closing, the writer would like briefly to discuss the relative effects of inertial and frictional forces on the motion of such small suspended particles as papermaking fibers. So much thinking of the past has been based on misleading analogies, such as the motion of logs in rivers, that this seems to be desirable. To those who have worked in the field of hydrodynamics it would probably be sufficient to point out that, for the same fluid and relative velocity, the Reynolds number for a log is of the order of 10,000 times that for a typical papermaking fiber! The following example provides an excellent illustration of the overwhelming effect of frictional resistance. We consider the motion of a sphere of mass m and radius r suspended in water which is flowing in a duct of such design that the water accelerates. For various accelerations does the sphere lag the stream appreciably, or is the viscous traction stress of such importance that there is practically no lag? The problem can be solved almost rigorously if we choose a sphere, and the result for a sphere should be the more convincing because of the larger specific surface of an elongate body like a fiber. We choose an acceleration field such that the velocity increases with distance and time from $x = 0$ and $t = 0$ in accordance with the equivalent expressions,

$$v = v_0(1 + kx)$$

and

$$v = v_0 e^{v_0 kt}$$

Application of Newton's Second Law and of Stokes' expression for the viscous drag on a sphere results in the differential equation,

$$d^2x/dt^2 + a(dx/dt) - av_0kx = av_0$$

in which $a = 9\mu/2\rho r^2$, μ is the viscosity of the water, and ρ is the density of the sphere augmented by an amount to account for the inertia of the surrounding fluid; the latter is given a value of 2 grams per cu. cm. which will more than allow for the inertia of the fluid in view of the observation that the effective density of papermaking fibers in water is usually close to 1 gram per cu. cm. The solution of this equation is

$$dx/dt = [1/k(a_1 - a_2)]\ [a_1(kv_0 - a_2)\, e^{a_1 t} - a_2(kv_0 - a_1)e^{a_2 t}]$$

in which

$$a_1 = (-a + \sqrt{a^2 + 4av_0k})/2$$

and

$$a_2 = (-a - \sqrt{a^2 + 4av_0k})/2$$

When $4v_0k$ is much smaller than a, this equation is numerically equivalent, very nearly, to v_0 exp (v_0kt), that is, the velocity of the particle is almost indistinguishable from that of the water (the retarding effect of inertia is almost completely negligible). A numerical example will illustrate this. If, at some point before the slice the velocity v_0 is 200 cm. per sec. and the speed doubles in a space of 10 cm., v_0k is 20 sec.$^{-1}$. The viscosity of water is about 0.01 poise and if the radius of the sphere is 0.0015 cm. (a diameter of 30 mu), a is found to be 10,000 sec.$^{-1}$. Numerical calculation shows that the speed of the sphere is almost indistinguishable from that of the water, even after a travel of 10 cm. in the assumed field of acceleration. Calculation shows that, after the water has moved a distance of 17.20 cm. from the point at which the speed is 200 cm. per sec., in the *same time* the sphere has moved 17.15 cm., which means that a fiber would stay with the water at least as well as this. This kind of discussion has been extended to other phenomena in zones of acceleration, such as aligning tendency of individual fibers, stretching and partial disruption of fiber agglomerates, and other phenomena which have been directly observed by Bryant and Moss.

Of course, in a powerful field of centripetal acceleration, such as in a centrifuge, fibers will move away or toward the axis of rotation with appreciable relative speed according as the effective density of the fibers is greater or less than that of water. It is dubious that centripetal acceleration in vortex motion in the headbox could, in itself, produce appreciable relative movement between fiber and water. For example, a vortex having an angular velocity of 25 radians per sec. at a radius of 2 cm. would possess, at that radius, an acceleration of 1250 cm. per sec.^{2}. In the numerical example chosen above to illustrate the smallness of lag of a suspended sphere, the initial acceleration was 4000 cm. per sec.^{2}, and we saw there that the relative movement between the particle and water was very small. Insofar as the relative movement between fibers is concerned, we suspect that the well-known mixing action of eddies, occasioned by collision and mechanical interaction between vortices, is the major effect of turbulence.

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Fiber Motions and Flocculation

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During flow through the headbox and slice and onto the wire of a paper machine, velocity gradients are established in the stock. Previous experimental work has shown that these velocity gradients are important in fiber flocculation. This paper summarizes the results of an experimental study of the rotations and collisions of spheres, rigid cylinders, and wood fibers caused by velocity gradients in which the liquids are suspended. This work has been carried out to shed further light on the way in which fibers aggregate. The rotations, spins, and orbits of the model particles show good agreement with theoretical predictions. Those executed by fibers are complicated by the bending which occurs and by their irregular shape. The collisions of spheres have been studied in some detail. When two neutral spheres collide, a doublet which persists for a definite and predictable time is formed. This leads to a purely hydrodynamic association into doublets, triplets, etc. Collisions between cylinders are more difficult

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to characterize, but appear to involve collisions of orbits rather than actual contact. Collisions of fibers are still more complicated, but it has been shown that, on collision, two fibers can twist around one another and rotate as a doublet for a number of complete rotations; this is believed to be the first step involved in the flocculation of fibers in papermaking stocks.

In the passage of the stock through the headbox and slice, and down the wire of a fourdrinier machine, differences in velocity are generally established between neighboring elements. Experiments have shown that these velocity gradients play an important part in determining the extent to which the fibers are flocculated, and have led to the conclusion that, at the fiber concentrations and under the conditions of flow met in practical papermaking, fiber bundles are generally, but not necessarily exclusively, formed by a purely mechanical entanglement of fibers as a result of the characteristic translational and rotational motions of individual fibers and fiber aggregates in velocity gradients (*1–4*).

In this paper it is proposed to outline a number of experiments which have been carried out to determine how suspended particles behave in velocity gradients. Rotations, collisions, and other interactions of model particles, such as spheres and rigid cylinders, and of

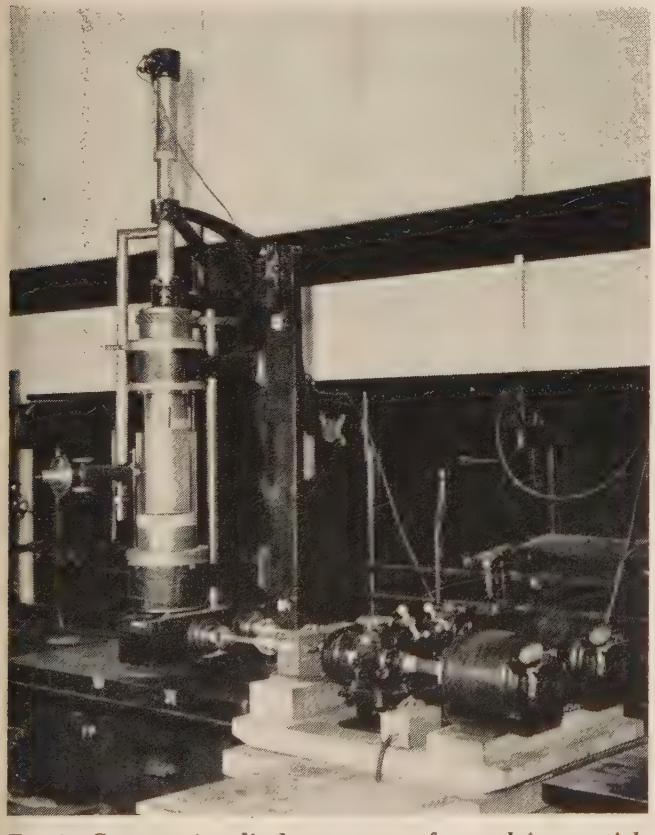

Fig. 1. Concentric cylinder apparatus for studying particle motions and interactions in a velocity gradient

wood fibers have been studied following a course whose theoretical foundations have been laid in an earlier paper (*4*). The phenomena which are described are basic to an understanding of the mechanism of fiber flocculation as well as of a number of properties of fiber suspensions.

THE VELOCITY GRADIENT METHOD

The experiments on particle motions and interactions were conducted in a special Couette-type apparatus (shown in Fig. 1) consisting essentially of two precision-bore concentric glass cylinders which can be rotated in opposite directions by separate driving mechanisms

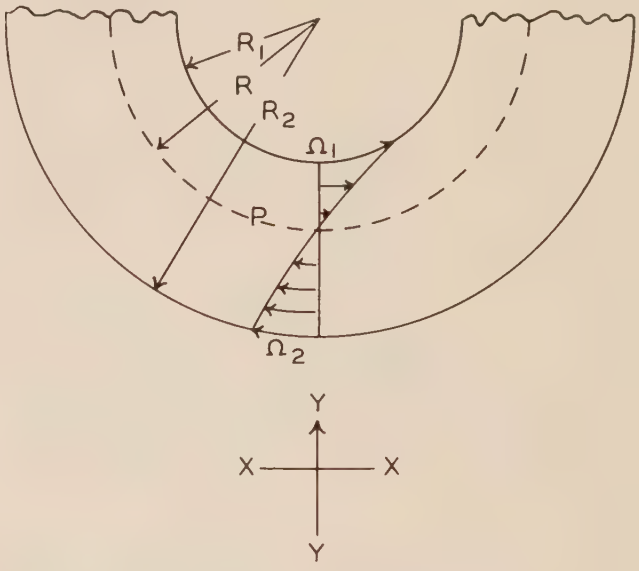

Fig. 2. Principle of the Couette apparatus. The cylinder speeds are manipulated so that the translational velocity of the center of the particle (at P) is zero. The Z axis of the rectangular coordinate system is parallel to the axis of rotation of the two cylinders; (after (5))

whose speed can be varied continuously. The suspended particles are placed in the annulus between the two cylinders and are viewed through a microscope which can be moved in all three dimensions and whose axis is directed at right angles to the axis of rotation of the Couette cylinders. If a rectangular coordinate system is established with the X, Y, and Z axes, respectively, parallel to the direction of fluid motion in the annulus, to the direction of the microscope axis, and to the axes of the Couette cylinders (see Fig. 2), then the particles are seen as projections on the X-Z plane of the coordinate system thus defined.

A single particle can be arrested for detailed observation in the field of the microscope by manipulating the mechanical drives so as to bring the stationary liquid layer (shown as a broken circle in Fig. 2) into coincidence with the center of the particle at P (Fig. 2). The fluid in the neighborhood of P, which is taken as the origin of the coordinate system, thus undergoes shear motion defined by $u = Gy$, v, $w = 0$, where u, v, and w are the translational velocities in the X, Y, and Z directions. G is the velocity gradient at P, and can be calculated (*5*) from the speeds of rotation and the diameters of the Couette cylinders with an absolute precision of about 1:1000.

To ensure laminar flow and to avoid gravitational and centrifugal sedimentation, the particles are usually suspended in a highly viscous medium; corn syrup having a viscosity of about 50 poises was used for this purpose. To observe the various phenomena in detail, the experiments were carried out at very low velocity

gradients with 2.5 sec.$^{-1}$ as an upper limit. It is considered that under these conditions effects due to particle accelerations, which cannot be treated theoretically and which would, in any case, considerably complicate the observations, were absent.

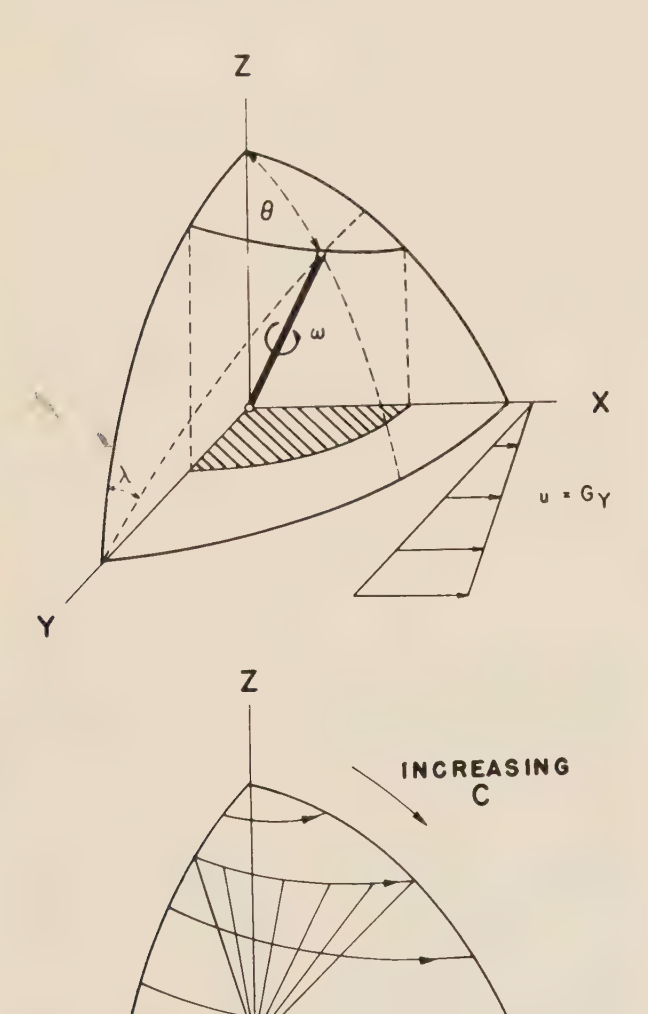

Fig. 3. A spherical elliptical orbit of a rotating cylinder (upper portion). In studying these orbits experimentally, the angle λ is measured as a function of time. A series of orbits corresponding to various values of the orbit constant C is shown in the lower portion

This arrangement proved to be highly successful in studying the rotations and interactions of model particles such as tiny glass spheres (20 to 150 mu diam.), smooth rigid cylinders (glass, Dacron Polyester, nylon, etc., 10 to 20 mu diam.), and pulp fibers. Detailed results of these experiments will be found in separate publications (*5–9*), but an outline of the salient findings, particularly those bearing on the problem of fiber flocculation, is given here.

ROTATIONS OF SINGLE PARTICLES

Spheres

When a tiny glass sphere is introduced into the apparatus and is located at P (Fig. 2), it can be seen to spin about the Z axis at a constant angular velocity. The direction of spin is the same as that of the outer Couette cylinder and for the case shown in Fig. 2 is clockwise. This steady rolling motion, which is caused by the uneven viscous drag of the sheared liquid, was originally predicted by Einstein in his well-known analysis of the viscosity of suspensions of spheres. The measured values of the periods of rotation for a range of particle sizes and velocity gradients agree within the limit of experimental error (0.1%) with the theoretical value (*5, 10, 11*) given by

$$T_1 = 4\pi/G \qquad (1)$$

Straight Rigid Cylinders

Smooth rigid cylinders also rotate but, because of the lack of symmetry, their behavior is more complicated. The rotational motion is, however, governed only by the ratio of length to diameter (the "axis ratio") and not by the actual size.

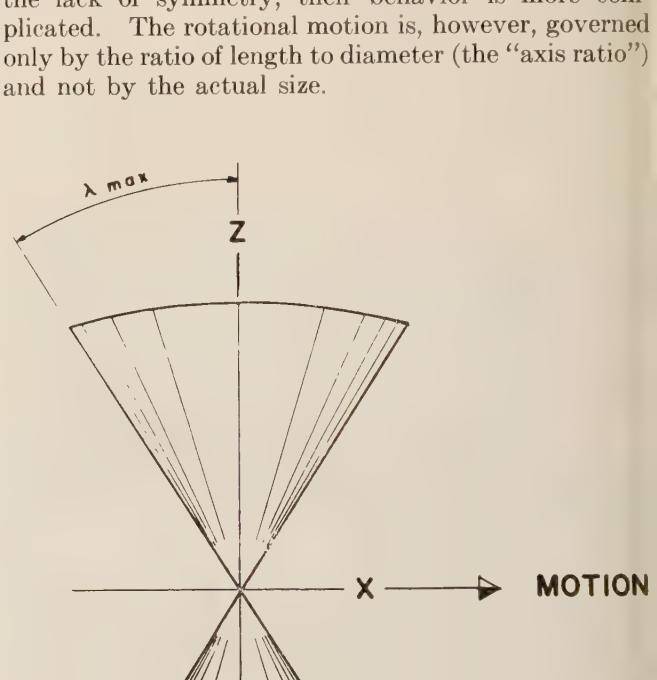

Fig. 4. Observed X-Z projections of a rotating cylinder at equal time intervals during one-half rotation in an orbit depicted in Fig. 3. The angle $\lambda_{max.}$ can be used to calculate the orbit constant

The ends of a single rod rotate about the Z axis in a spherical elliptical orbit, as predicted by Jeffery for prolate spheroids (*1*) and as discussed before (*4, 5*), so that the rotating rod describes a surface which, very roughly speaking, is a double cone. The projection of this orbit on the X-Y plane is an ellipse. A family of

such orbits is shown as the heavy lines of Fig. 3. Each orbit is characterized by an orbit constant C, related to the eccentricity of the spherical ellipse, which can vary from zero, when the principal axis remains parallel to the Z axis, to ∞ when the ends of the particle describe a great circle in the X-Y plane. At the same time the particle spins about its principal axis with an angular velocity ω predicted to be

$$\omega = G \cos \theta/2 \qquad (2)$$

where θ is the instantaneous angular displacement of the ends of the particle from the Z axis. This type of rotation is subsequently called "axial spin"; the rotation of the particle axis about the Z axis is called simply "rotation." It should be noted that when $\theta = 0$, i.e., the particle is parallel to the Z axis, the axial spin is the same as that of a sphere (equation (1)).

In the experiments the particles are viewed as projections on the X-Z plane and the angular displacement λ of the projection of a particle from the Z axis can be measured at any instant. It can readily be shown from Jeffery's equations that the period of rotation of the particle about the Z axis is

$$T_2 = 2\pi r/G \qquad (3)$$

and that the angle λ varies with time according to the equation

$$\tan \lambda = Cr \sin 2\pi t/T_2 \qquad (4)$$

where

T_2 = period of rotation
t = time
r = axis ratio = length/diameter
C = orbit constant

It follows from the last equation that the particle should appear to rock back and forth between the angles $\pm \lambda_{max.}$ given by

$$\tan \lambda_{max.} = Cr \qquad (5)$$

as shown in Fig. 4. Thus by measuring $\lambda_{max.}$ the orbit constant C can be computed.

The measured periods of rotation vary inversely with G and for a given axis ratio are independent of the particle orbit, but are 30 to 40% lower than predicted by equation (3). It will be recalled that equations (3), (4), and (5) were derived for an ellipsoid of revolution (i.e., a cigar-shaped particle); the lower values for a cylinder are to be expected from the difference in shape (*2*). The three equations can be applied to cylinders, however, by substituting r_e the "equivalent ellipsoidal axis ratio" for the actual value r, where r_e is computed from the measured period of rotation using equation (3). Table I gives values of the ratio

Table I. Equivalent Ellipsoidal Axis Ratios of Rigid Cylinders

Calculated from measured periods of rotation

	Axis ratio	
r	r_e	r_e/r
20.4	14.3	0.70
68.4	38.0	0.56
115.3	60.5	0.53

r_e/r for several values of r from 20 to 115, covering the range of axis ratios in wood fibers.

Prolonged observations over hundreds of successive particle rotations show that the orbit, determined from observations of $\lambda_{max.}$, remains constant except for a slow random drift due to convection caused by unavoidable temperature gradients in the apparatus.

The actual details of the orbits, determined by measuring the variations of λ with time, are found to be in excellent agreement with equation (4). An example is shown in Fig. 5.

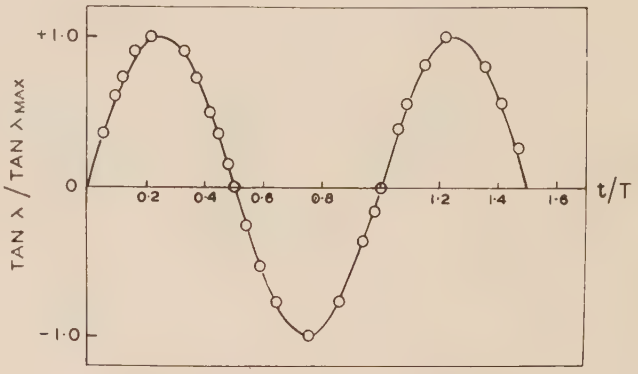

Fig. 5. The variation of the angle $\lambda_{max.}$ with time for a rotating straight Dacron polyester filament of axis ratio 90. The points are calculated from the experimentally determined values while the curve is calculated from equation (4); after (8)

The axial spins predicted by equation (2) have not been studied qualitatively but are observed to be in qualitative agreement, i.e., ω is zero when the particle rotates in the X-Y plane ($C = \infty$, $\theta = \pi/2$) and increases as the orbit constant C decreases until it reaches a maximum when the particle is parallel to the Z axis (θ, $\lambda_{max.}$, $C = 0$).

The foregoing remarks apply to straight particles, but with some modification, also apply to rigid filaments curved in circular arcs subtending angles less than 90°, the upper limit of curvature in the particles thus far studied. Single particles rotate in unchanging orbits qualitatively similar to those of straight rods. Similar values of r_e/r, in which r is now computed from the chord length, are found when $C = \infty$, i.e., when the particles rotate in the X-Y plane and when the axial spin is zero, but become smaller as $C \rightarrow 0$ and the axial spin increases. When viewed in the microscope field, the axial spin is much more in evidence than is the case with straight particles. It is believed that the decrease in period of rotation (T_2) is due to the effect of spin in decreasing the effective axis ratio of the particle (*9*).

Wood Fibers

The motions of single wood fibers bear a relationship to those of the model particles discussed above but are complicated by a number of additional factors. Except for highly lignified fibers, such as those of groundwood and high-yield semichemical pulps, the fibers are found to be flexible, either being relatively uniformly flexible or, more often, having flexible joints where the bending is localized. In many substances the joints can only bend in one direction but not in the other, i.e., they are knee joints. It is reasonable to suppose that these joints result from localized fracture

of the primary wall, but this point remains to be explored. In the unstressed state the fibers are rarely straight, and the bends are not uniform. Furthermore, instead of being circular in cross section, they are usually flattened into a ribbon especially when they have been dried and/or beaten.

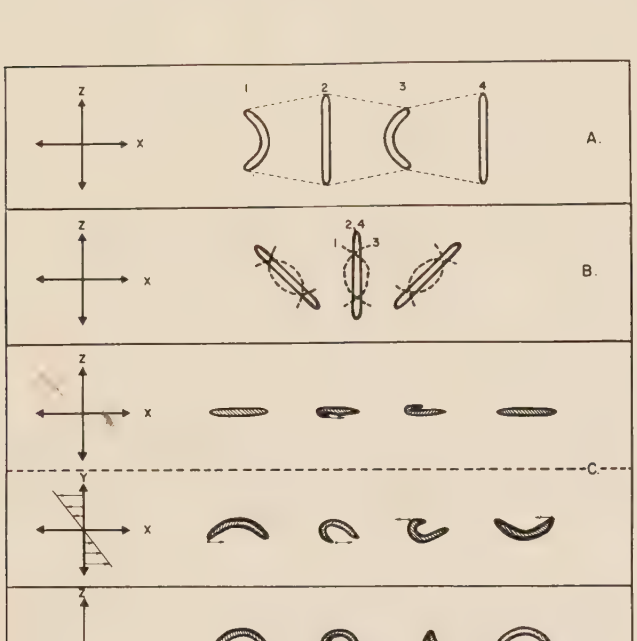

Fig. 6. Modes of rotation of flexible wood fibers. A is a flexible spin, B is a flexible rotation with superimposed spin, C is a snake turn, and D is a loop turn; after (9)

The wide variations in structural characteristics and dimensions of fibers in a single sample make systematic observations difficult. Nevertheless it has been possible to systematize the motions into the following general classes (*9*):

1. *Rigid Rotations.* Qualitatively similar to those of the corresponding rigid filaments. Sharp bends have a pronounced effect on axial spin.

2. *Flexible Spin.* Main axis parallel to Z axis, i.e., $\lambda_{max.} = 0$. Bending when in the X-Z plane (the plane of shear) and tending to straighten out when in other spin positions.

3. *Flexible Rotation.* Main axis displaced from Y axis, i.e., with $0 < \lambda_{max.} < \pi/2$. Rotation in an approximately spherical elliptical orbit (Fig. 3) with a superimposed flexible spin.

4. *Snake Turn.* Main axis rotates close to X-Y plane, i.e., $\lambda_{max.} \rightarrow \pi/2$. Straight when pointing in X direction (direction of flow). One end starts to bend, with bend passing along the fiber from the leading end (the head) to the trailing end (the tail) until particle axis has rotated 180°. Repeated with same end leading until rotation is completed; occasionally the head will bend to start a new half turn before tail straightens out. This often results in a closed loop or spiral. Behavior varies according to whether fiber is uniformly flexible along its length or has flexible joints.

5. *Loop Turn.* Main axis rotates as for a snake turn, but with both ends forming a head in opposite Y directions until half rotation is completed and fiber straightens out in X direction.

These are illustrated schematically in Fig. 6. The most commonly observed is the "snake turn." Several evenly spaced frames from cinephotomicrographs of a semirotation of the latter kind are shown in Fig. 7. Contrary to expectation, the "loop turn" is rarely observed; evidently the fibers do not possess the necessary uniformity in cross section and flexure along their length.

Unlike the single rigid particles which move in constant orbits with C varying from 0 to ∞, a single flexible fiber on prolonged shearing tends to shift either to $\lambda_{max.} = 0$ or to $\lambda_{max.} = \pi/2$, i.e., toward a flexible spin or a snake turn orbit, the preference being for the latter. The intermediate steps involved in the drift have been studied (*9*) but need not concern us here.

The bending stresses in the fibers are generated by the shearing action of the liquid and, by analogy with the deformation stresses which have been calculated around a sphere (*11*), may be expected to be proportional to the product $G\eta$, where η is the viscosity of the fluid. Since the fluid used in these experiments has a viscosity about 5000 times that of water, the shear rates in papermaking suspensions at which similar distortions would be observed would be at correspondingly higher shear rates. While most observations are

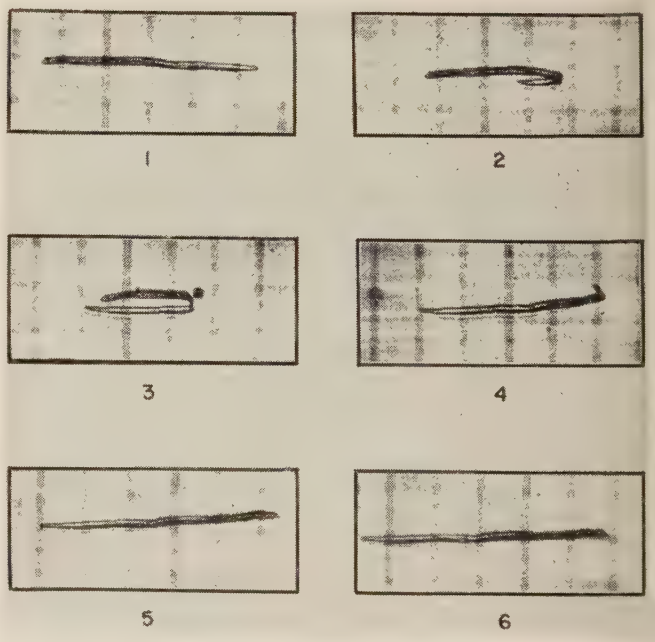

Fig. 7. Photographs of a snake turn of a pulp fiber during a half-rotation; after (9)

for practical reasons made at about 1 sec.$^{-1}$, there appears to be no lower limit of G at which the same behavior is observed. In other words, it is probable that pulp fibers bend similarly when they flow through the paper machine.

Measurements of periods of rotation, T_2, of "snake

turns" yield values which are about one-tenth those of rigid cylinders of corresponding axis ratio. This is not surprising in view of the greatly reduced effective axis ratio caused by the bending.

COLLISIONS AND INTERACTIONS

Thus far we have considered only the rotations and spins of single particles. When the liquid contains a multitude of particles, they either collide or interact with one another. These interactions have a number of important consequences.

Spheres

Let us first consider the simplest case, that of spheres. When a dilute suspension of glass spheres (less than 1.5% by volume) is introduced into the apparatus, and one is selected for observation it is found that it continues to spin in accordance with equation (1) until another sphere approaches and appears to collide with it. These collisions are of interest in connection with fiber flocculation as well as with other phenomena and have been studied in considerable detail (*6*).

The manner in which two-body collisions can occur is readily visualized. A single sphere moves with the same translational velocity as the undisturbed liquid in the same shear plane (the X-Z plane). Two spheres in different shear planes will therefore move at different velocities in the X direction. If the path of the center of one sphere carries it into the "collision sphere" described about a second sphere having a radius equal to the sum of the radii of the two spheres, a disturbance of the motion of both spheres must occur. It is found that when the two spheres do not differ by more than 100% in radius, the path of approach is a straight line up until the instant of "collision" when a doublet forms (*6*).

An analysis of the mechanics of collision leads to the following relationship for f, the number of collisions suffered by each particle/unit time in a suspension of equal-sized spheres,

$$f = {}^4/_3 a^3 nG = 8cG/\pi \qquad (6)$$

where

a = diameter of spheres
n = number per unit volume
c = volume fraction of spheres in the suspension
G = velocity gradient

A similar relationship can be derived (*7*) for collisions between spheres of different size.

Both relationships have been confirmed by direct measurements of two-body collision frequencies over a range of particle sizes, concentrations, and velocity gradients. A series of measurements (*6*) on equal-sized glass spheres of diam. 137 mu over a total of 1400 collisions yielded a value of $f_{observed}/f_{calculated} = 1.01$; this agreement is well with the estimated experimental error.

Each collision is found to be sharply defined. The experimentally established details of the collision process for equal-sized spheres are illustrated schematically in Fig. 8. The behavior may be summarized as follows:

1. When two colliding spheres approach one another, an abrupt change in the motion of each occurs and the contact between one pair appears to the eye to be real.

2. The doublet formed by the two colliding spheres exists for a time as a definite entity. It rotates as a rigid dumbbell, without rolling or sliding motion, at a constant angular velocity about the Z axis, until a mirror image of the initial angle of contact ϕ_0 (Fig. 8) is described. The particles then separate at the same Y and Z coordinates as they possessed before collision.

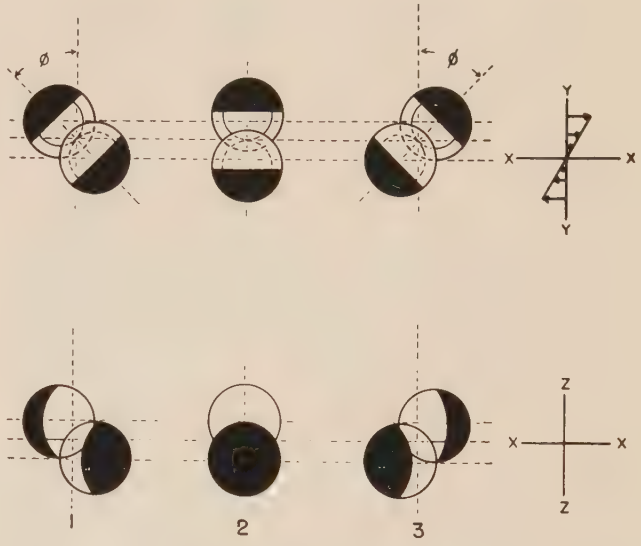

Fig. 8. Projections of doublet formed by two colliding spheres of equal size for beginning (1), mid-point (2) and end (3) of a collision; after (6)

3. Each doublet has a finite life which depends upon the relative positions of the two particles at initial contact. It is possible to calculate the distribution function of doublet lives, and from them the mean and maximum lives. These relationships were confirmed by direct measurement (*6*).

The fact that neutral rigid spheres form doublets having finite and calculable lives has a number of interesting consequences of which one may be mentioned here. If spherical particles are uniformly dispersed in a liquid which is sheared in the manner described above, or more generally by stirring, particles are brought into collision with one another and remain associated for a definite period of time. It has been shown (*6*) that the average life of a doublet τ is given by

$$\tau = \pi/G \qquad (7)$$

It will be evident that, as stirring proceeds, a steady state will be reached in which the number of doublets formed in unit time is equal to the number of doublets which die by separation. Since a doublet exists for a finite time, it is reasonable to assume that it can undergo a further collision with a singlet and thus form a triplet, and so on. Thus we can see that a hydrodynamic association can occur between neutral particles, purely as a result of the differential translational motion of the particles due to velocity gradients.

It is readily shown that the steady-state number of doublets per unit volume is $fn\tau/2$ from which it follows that the volume fraction of doublets c_2 is

$$c_2 = 8c^2 \qquad (8)$$

Equation (8) is only valid at low concentrations

since both the depletion of singlets and the formation of triplets, etc., have been ignored. Calculated concentrations of doublets are shown in Table II for various total concentrations. Here it is seen that at concentrations as low as 2% by volume, 15% of the total number of spheres are associated in doublet form.

Table II. Steady-State Concentration of Doublets in a Suspension of Spheres

Volume, % c	*Volume, %* c_2	$100c_2/c$
2	0.3	15
4	1.3	32
8	5.1	64

While the collisions observed appear to be real, proof of true contact is lacking. However, when air bubbles are studied, it is found that the interacting pair coalesce after a time. This suggests that the particles approach each other within a distance of at least 10 to 20 A to allow surface tension forces to come into play.

Rigid Cylinders

"Collisions" occur in a suspension of rigid cylinders but as may be expected, the details are considerably more complicated than for spheres. The collisions need not involve actual contact of the particles, but merely an interpenetration of orbits. Since the volume generated by a cylinder moving in orbits of the kind discussed earlier is considerably greater than its real volume, the collisions are much more frequent than in suspensions of spheres of the same concentration (*4, 8*). In a dilute suspension of cylinders, it can be shown that isolated particles move in exactly the same way as the single particles discussed previously, i.e., in fixed orbits and with periods of rotation according to equations (3) and (4).

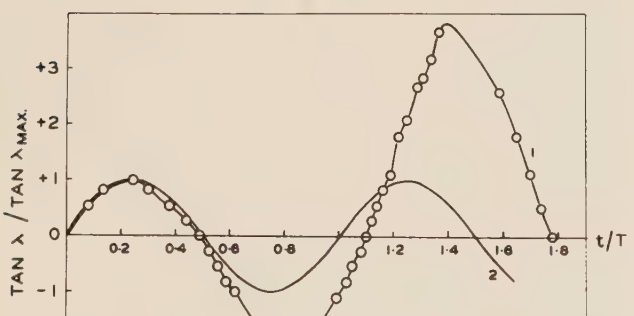

Fig. 9. The variation of the angle λ with time for a Dacron polyester filament of axis ratio 90 undergoing an interaction with another similar particle (curve 1). Curve 2 is that of a single undisturbed particle (Fig. 5 and equation (4)). Note the change in the angle $\lambda_{max.}$ and in period caused by the interaction; after (8)

When two particles approach so that their orbits interpenetrate, they become associated for a time and then separate; during the life of the doublet, each particle moves in an orbit different from that expressed by equation (4). After separation, each particle has an orbit constant C different from that existing before collision. This is illustrated in Fig. 9 where it is seen that a collision, in addition to knocking each particle into a new orbit, also causes it to undergo a change in rotational phase.

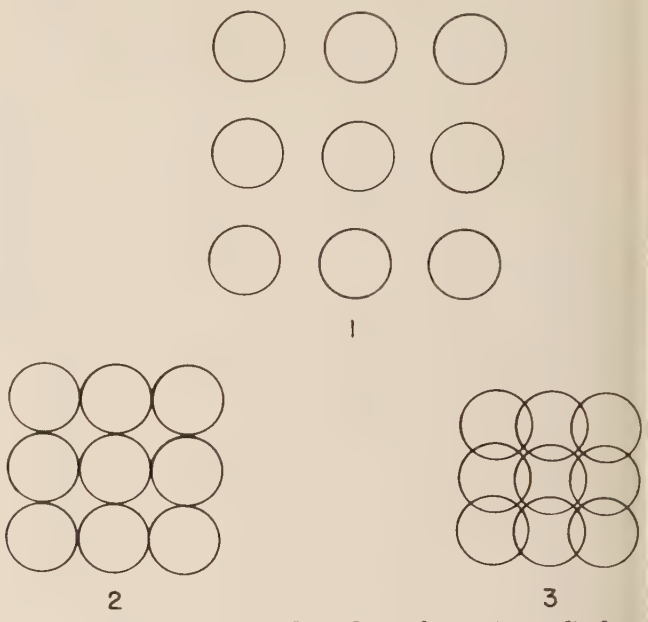

Fig. 10. Space described by orbits of rotating cylinders: (1) below, (2) at, and (3) above the critical concentration (schematic)

The variation in rotational velocity of a straight cylinder at various positions in its orbit can be expected to yield preferred orientations in various reference planes (*4, 8*). When a dilute suspension in which the particles have an initially isotropic distribution is sheared, it is found that there is a gradual drift in the instantaneous distribution function of λ's toward a steady state with a preferred orientation in the direction of flow. This can only be explained by the changes in C and rotational phase which accompany collision. It should be noted that the equilibrium state is a dynamic one.

As the concentration is increased, the frequency of two-body encounters increases as the particle orbits become more and more crowded, until a point is reached when a rotating cylinder is under more or less continuous interaction. This has been observed experimentally to occur at concentrations of less than 0.05% by volume in particles of axis ratio 20 (*8*).

Fibers

The interaction of fibers is similar to that of rigid cylinders, but is further complicated by bending. At very low concentrations, e.g., less than 0.05% by weight, which is the upper limit of concentration at which single fibers can be followed in the microscope field, the encounters are very frequent and cause the particles to move in erratic orbits.

In many instances when two fibers collide, particularly when they are undergoing flexible rotations and/or snake turns, they become entangled around one another and execute a number of rotations as a pair, analogous

to a doublet of spheres, before disentangling and separating. Although only a limited number of observations have been made, it appears that this entanglement is facilitated by bending of the fiber, i.e., is favored by increased flexibility. At slightly higher concentrations, fiber aggregates having a dynamic structure, i.e., aggregates which are continuously gaining fibers by collision and losing them by disentanglement, can be observed.

CONCENTRATION EFFECTS

The foregoing observations on cylindrical particles and fibers have been made at concentrations much lower than in the stock fed to the headbox of a paper machine. As we have seen, a rotating fiber sweeps out a volume considerably greater than its actual volume. It is evident, therefore, that as the concentration of the suspension is increased, a critical concentration will be reached, as shown schematically in Fig. 10, above which the fibers cannot undergo unimpeded rotations, simply because there is insufficient space in which to move. Under these conditions, it is to be expected that the equations describing the motions and collisions discussed above are no longer applicable.

An estimate of the order of magnitude of the critical concentration can be made by assuming that the statistically averaged shape of the space enclosed by a rotating fiber is a sphere whose diameter equals the particle length. It is readily shown (*4*) that

$$\frac{\text{Effective volume of rotating particle}}{\text{Actual volume of particle}} = 2r^2/3 \qquad (9)$$

and that the critical concentration c_0, expressed as a volume per cent, is given by the relation

$$c_0 = 3/2r^2 \qquad (10)$$

The c_0 given by equation (10) gives a lower limit since the extreme case of a spherical orbit has been assumed. In the case of a rigid rod, a more realistic shape is that of a cylinder with an elliptical cross section. In this case, the volume of the orbit can be readily shown to be a function of the orbit constant C. Calculations based upon the steady-state distribution functions of the orbit constants which have been established experimentally show that the assumption of the simple spherical orbit does not introduce a very serious error in calculating c_0 (*8*). On the other hand, when we are dealing with flexible fibers, the effective length of the fiber is diminished by bending by an amount which presumably depends upon the flexibility of the fiber. This will have a further effect of reducing c_0, but the amount cannot be estimated since we do not yet have any quantitative measure of fiber flexibility.

Table III gives values of c_0 calculated from equation (10) for various values of the axis ratio r covering a range representative of wood fibers. It should be noted that the concentration is expressed as volume per cent. To convert to a weight/volume basis the values shown should be divided by the hydrodynamic specific volume which is of the order of 1 to 3 cc. per gram for pulp fibers. It will be noted that the critical consistencies are well below those of conventional papermaking stocks.

Table III. Critical Concentrations for Free Rotations of Rigid Cylinders

Axis ratio	c_0, *% by volume*
20	3.7×10^{-1}
40	9.4×10^{-3}
60	4.2×10^{-3}
80	2.2×10^{-3}
100	1.5×10^{-3}

Growth of flocs by purely mechanical entanglement above the critical concentration can be visualized to be somewhat similar to that observed in the experiments described above. When a suspension is sheared, fibers collide and entangle with one another; at the same time the flocs are progressively broken down, so that a dynamic equilibrium can be established between the growth of flocs by the collision mechanism described, and their breakdown by the disruptive action of the shear stresses. It has been shown that the extent of flocculation decreases as the velocity gradient increases (*1*). This can also be demonstrated in the Couette apparatus at concentrations in excess of the critical. It has been observed that if a pulp suspension upward of 0.1% in concentration is sheared for a time, and the motion is then suddenly stopped so that the prevailing structure is frozen, the extent of flocculation, as judged visually, decreases as the shear rate is increased. In a further series of experiments in which pulp suspensions were passed through a tube $^7/_8$ in. in diameter and at consistencies up to 0.7%, fiber dispersion was promoted, apparently without limit, by increasing the stock velocity up to 700 f.p.m. and hence the velocity gradient, and was hindered by increasing the fiber concentration (*7*). The interpretation of these experiments, however, is complicated by the fact that the rate of shear could not be specified since anomalous flow patterns were developed in the stock. The results have, however, demonstrated that there is a close relationship between flocculation and flow behavior of pulp suspensions. In view of the observations made on particle motions and particle collisions, this is not surprising.

LITERATURE CITED

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Hydraulics of Flowbox and Slice

W. VAN DER MEER

The requirements for an ideal slice are discussed briefly. However, this paper is primarily concerned with the principle used in flowbox and slice design. The hydraulic principles are given for flow systems, canals, distributing rolls, whirls, vortices, changes in stock direction, bends, pipes, cross and flow spreading, and the slice. Baffle, airdome, and closed boxes are also reviewed.

UNTIL very recently all headboxes were designed on an empirical basis. Progress in design was slow, improvement being effected by trial and error methods in the field, there being little recognition of the fundamental principles involved and thus little coordination between the efforts of different mills.

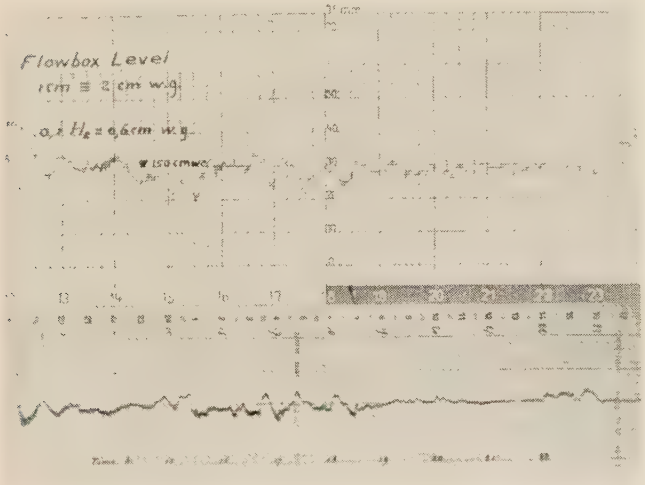

Fig. 1. Influence of power frequency on slice pressure

The science of hydraulics originally started in the same empirical way. The large quantity of data originally found were ultimately embodied into empirical mathematical relationships, and these often formed the basis of later theoretical treatment.

Application of the laws of hydraulics to those parts of a paper machine where stock is flowing necessitates a further progression, since the flow of stock differs from the flow of water. The mass forces involved are of the same order for both water and stock; the behavior of stock under flow, however, is not always as can be predicted by its apparent viscosity, thick stock being a type of Bingham fluid. These differences between stock and water are stressed in the parts which follow.

The ideal slice can be defined as one which gives an equal jet, so that even formation is possible; by this is meant an equal distribution of fibers for the smallest area considered, i.e., quality of weight per square inch not per square foot. Further spots of deviating concentration and flocs must be absent from the stock as it is delivered to the wire. To obtain this the slice must have:

1. A jet of even velocity profile right across the machine with absence of cross velocities in the jet.
2. A constant fiber distribution.
3. A high level of turbulence in the jet so that there is a random fiber distribution. A flat jet is needed on leaving the slice so that large-scale turbulence must be particularly avoided.

The methods of obtaining the above conditions are of less importance to the papermaker than the conditions that the installation should be (1) easy to clean; (2) reasonably easy to handle; (3) not expensive; and (4) perhaps more important in Europe, not consuming excessive power.

Certain fundamental requirements are common to all headbox installations; these are listed and briefly discussed below. The remainder of the paper from Canals onward discusses stock flow, headbox, and slice, assuming that these stated fundamental rules have been followed.

A constant rate of flow of stock and water to the slice is essential. Here it can be pointed out that what is meant is a rate constant when the time interval considered is very small. Clearly the rate considered in gallons per minute may be constant while the rate in gallons per 0.1 sec. fluctuates wildly.

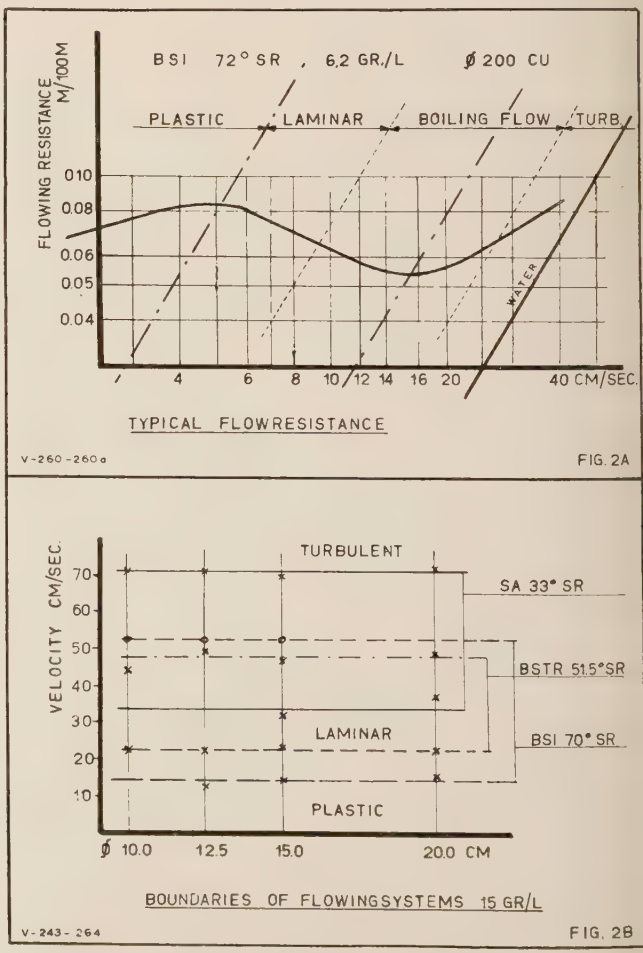

Fig. 2. Typical flow resistance

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Figure 1 shows the frequency variation and corresponding headbox level fluctuation on a typical machine.

The upstream installation must be constructed in such a way that there is no free fall of stock or water, thus preventing entrainment of air. To remove air once entrained is both expensive and difficult.

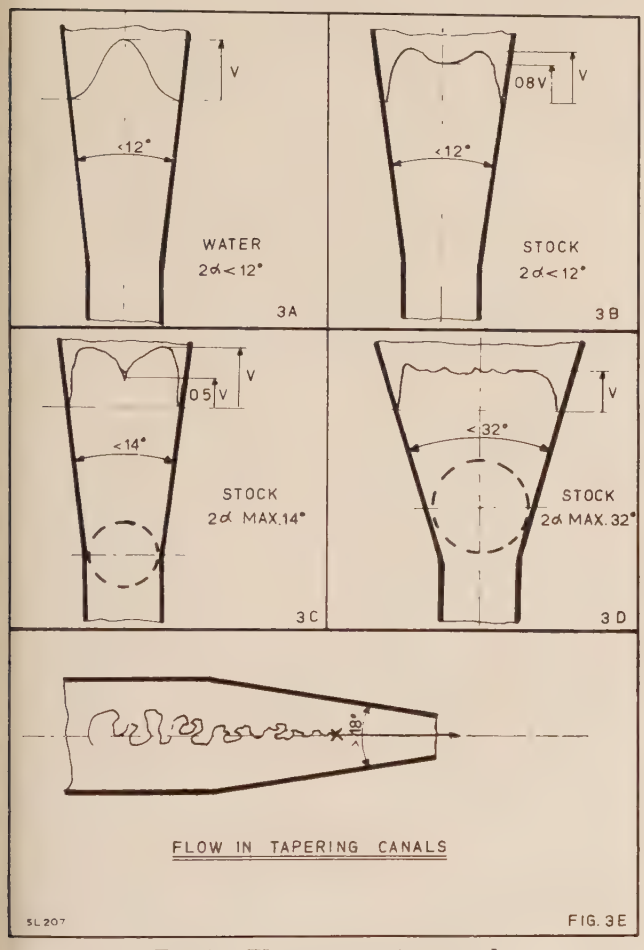

Fig. 3. Flow in tapering canals

The wire pit and screens, the screens and headbox, and parts of the headbox may all form oscillating systems. If the period of oscillation is a multiple of the screen frequency then resonance is possible, resulting in the possibility of oscillations of large amplitude. These oscillations can cause basis weight variations by changing both head and consistency in the flowbox. Such conditions can most easily occur when the pipe lines are short and wide with no pumps in them.

The time of oscillation can be calculated according to the formula:

$$T = 2\pi\sqrt{\frac{L}{g}\,\frac{A_1A_2}{A(A_1\cos\alpha_2 + A_2\cos\alpha_1)}}$$

where

T = cycling time in seconds
L = length of tube
A = area of pipe line
A_1A_2 = area of tanks
$\alpha_1\alpha_2$ = wall angles
g = gravity acceleration

The fact that we are considering a stock suspension does not affect the formula very much. For further data refer to Rouse (*1*).

One of the difficulties when endeavoring to calculate how to damp the system is how to choose the viscosity. For this purpose the apparent viscosity as found by Head (*2*) is applicable.

As an example, with screen surface and flowbox surface both 2 sq. m. and screens with 1 r.p.m., resonance can occur if one part of the screening surface is more open than the other provided the connecting pipe has a diameter of approximately 40 and 300 cm. long.

The principles used in flowbox and slice design and construction are considered in the next section. As this section is in parts very compressed, reference (*3*) should be consulted for full information. The third section of the review by the present author and J. Mardon will shortly be published in the *Pulp and Paper Magazine of Canada* and was delivered as a summary by O. J. Walker at the 1954 Summer Meeting of the Technical Section, Canadian Pulp and Paper Association.

CANALS

Flow Systems

Four systems of flow are defined, based on the investigations of Heller (*5*) and the author and his coworkers. See Fig. 2.

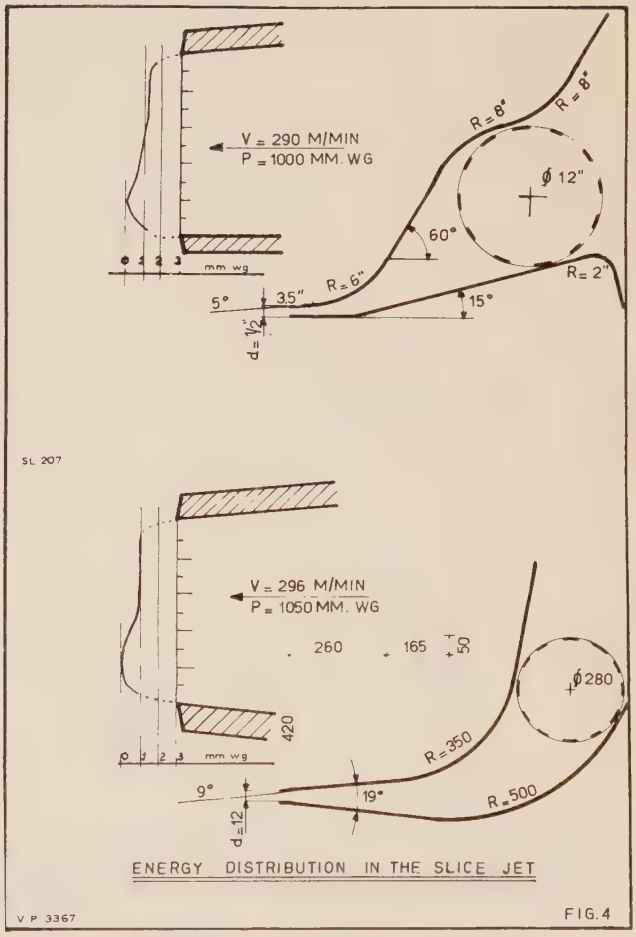

Fig. 4. Energy distribution in the slice jet

1. Plastic flow—not desirable in a flowbox.
2. Laminar—also not desirable as the flow is not stable.
3. Boiling flow—the most common. Here the stock is moving in masses, independently of each other. At the planes of

shear the resistance is low, and thus these masses retain their identity over considerable distances.

4. Turbulent—at which the fibers are moving freely along each other and which occurs only at velocities found in the slice and when the intensity of turbulence has a very high value, as behind an evener roll.

The flowing velocities in the last case are for:

Bleached sulphite cellulose	approx. 4 ft./sec.
Groundwood	approx. 6 ft./sec.
Unbleached sulphite	approx. 4 ft./sec.

for 0.5% consistency.

Widening Canals

For water Hamel (*6*) found that the maximum angle at which the flow will follow both walls will be: $2\alpha = 12°$. The author and his coworkers have confirmed this using their model flume. For 0.5% groundwood: $2\alpha = 11^1/_3°$ (Fig. 3B).

Distributing Roll

When the widening walls begin at the center line (Fig. 3C), $2\alpha = 14^2/_3°$. When beginning $^1/_2$ D earlier (Fig. 3D) $2\alpha = 32°$. Both are results of our own investigations (*7*) with groundwood of 0.6% consistency.

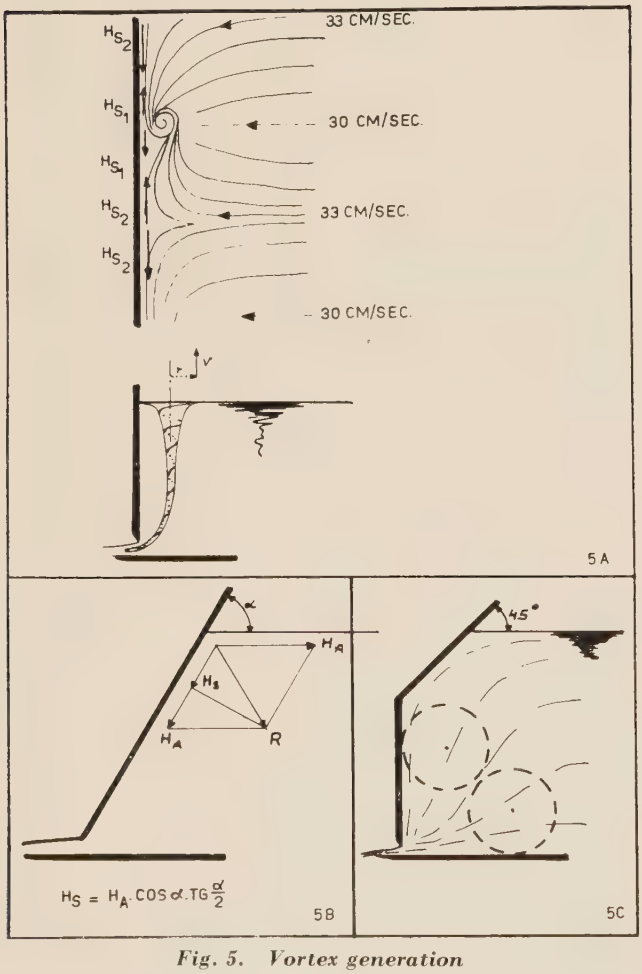

Fig. 5. Vortex generation

Diverging canals may be built, also according to the last system, much shorter, a wall tangent of $1:3^1/_2$ instead of 1:10.

Narrowing Canals

Free Canals. The theory of Hamel (*6*) says that the flow distribution of a *narrowing canal is very equal.* This does not mean that there exists no turbulence of high intensity! This may be seen in a free jet from a slice. This equal velocity may be one of the reasons why the flocs of the investigations of Moss and Bryant (*8*) would not turn.

Figure 4 shows that even the *influence of a bending*

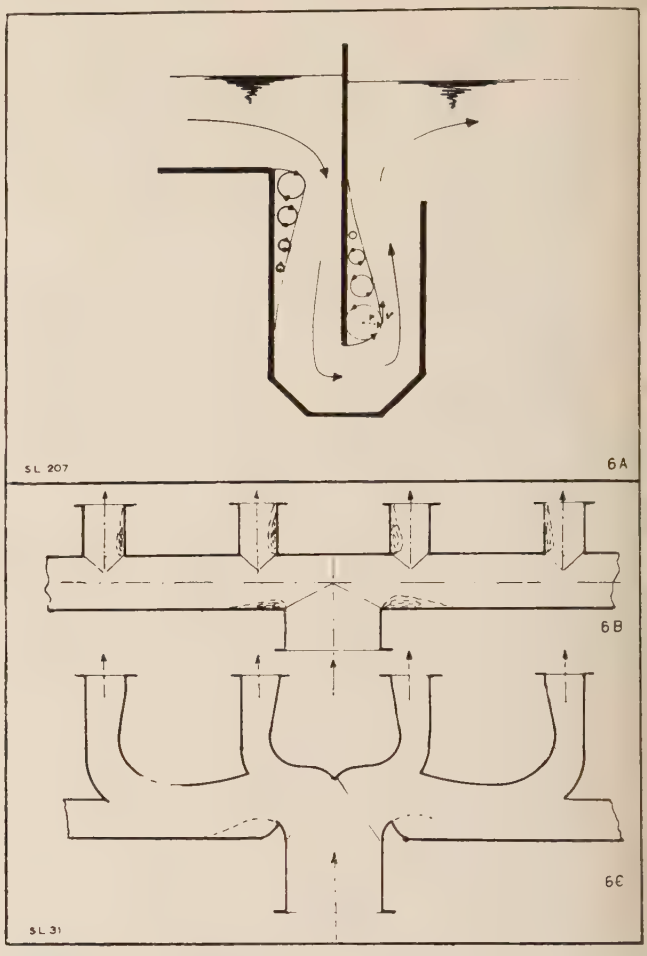

Fig. 6. Whirls in bends

of the slice *is equalized,* as measured with a pitot tube of 3 mm. diam. and water and 0.6% groundwood as flowing medium.

For a stable flow with equal velocity over the height of the jet, an angle of the slice lips of 10 to 20° is advisable, for the negative pressure Gough (*9*) calculated must be prevented. This would give reason for the air in the stock to come free. When the slice plates are polished sufficiently over the last part, say five openings' length, and the edges are straight and sharp, a jet may be observed having over its first length a glassy appearance due to the boundary layers from the slice lips, but further on the jet becomes rough again due to the inner turbulence, as may be seen very well with a stroboscope of 30 to 40H_z.

Distributing Roll. After a distributing roll we will get macroturbulence, especially when the free opening is less than 52% of the roll surface, as will be discussed later.

After a distributing roll 6 in. diam., 40% open, in a parallel canal, boiling flow continued to exist after $3^1/_2$ ft., though the velocity of the 0.6% groundwood was only 1 ft. per sec.

When the angle between the walls following the roll using the same distributor roll was narrowed to $2\alpha =$

10°, the amplitude of the macroturbulence was about $^3/_4$ in. in the last $^1/_2$ ft. Only when the angle was $2\alpha = 18°$ or more, was the flow quite straight there.

In a slice with a roll of 8 in. diam, and a length of 2 ft. at a velocity of 1200 ft. per sec., the colored stream coming from 1 ft. after roll was quite straight with water, but with 0.7% groundwood the amplitude was

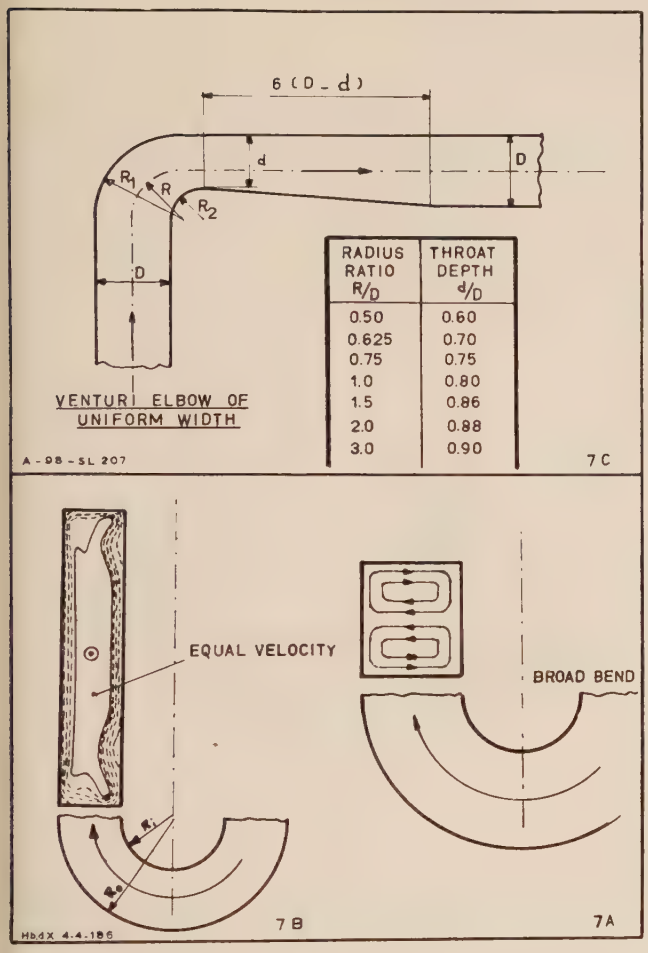

Fig. 7. Bends

about $1^1/_2$ in., due to the boiling flow behind the roll which was 46% open (*10*).

A roll being 52% open gave better results. In these tests the colored stream for detection of turbulence was introduced by a jet with constant rate of delivery. The flow below the surface was investigated using a lucite pipe with a mirror on the bottom. The flow below the surface was as described above for surface conditions.

Whirls

Free Vortices. When the stock surface is 3 ft. or less above the slice as occurs in old baffle boxes or high pressure boxes with air dome, the approach flow to a vertical wall must be very even, otherwise vortices will be generated (Fig. 5). A velocity difference of 30 to 33 cm. per sec. will give to a vertical wall a pressure difference of 1 mm. water column, which generates a secondary flowing velocity of 14 cm. per sec. When this forms a vortex with a radius of $r = 2.5$ cm., which can be diminished to 0.1 cm., when escaping through the slice, a vacuum of about 12.0 cm. water gage is created. Even when two thirds is lost as resistance, the remaining 4 cm. water gage have an influence on the flow rate on that place through the slice.

A good method of detecting these vortices is the use of electronic pitot tubes with continuous recording as reported in the discussion of this paper by Mardon. These whirls show as occasional very large pressure fluctuations.

A remedy is *tilting the frontwall* according to Fig. 5C. Now the secondary energy is diminished to $H_s = H_A \cos \alpha \, tg \, \alpha/2$, though there is a minimum at $\alpha = 45°$ (*11*). At $\alpha = 60°$ the secondary energy is diminished to 50%. These vortices may be recognized by their shifting along the slice.

Fixed Vortices. A vortex is fixed when about 180° of its circumference is a fixed wall or stream. The danger of these whirls is that under pressure their diameter becomes smaller and so at the place of higher pressure there will be a wider passage (Fig. 6A).

With a passage of 40 cm. width, after the baffle, of a baffle flowbox (Fig. 6A) and with a vortex after the baffle in that passage of 5 cm. radius, a change of pressure of as little as 1 mm. water gage can cause a disturbance due to compression of the vortex cylinder by

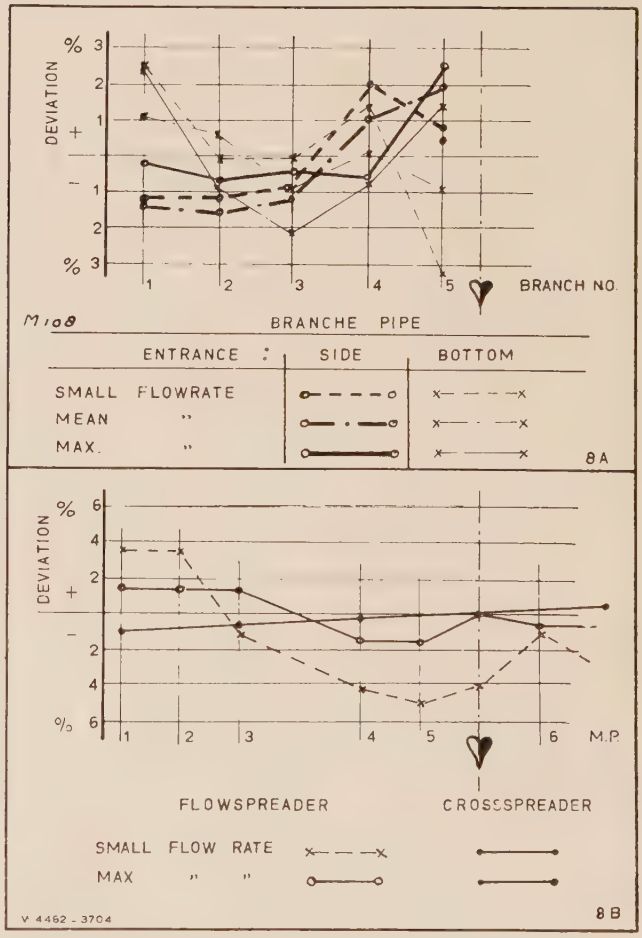

Fig. 8. Flow rate deviation of distributing pipes

changing the centrifugal components of its pressure, and thus causing a higher flow rate at that point, which in turn causes cross flow of stock, Therefore it is necessary to avoid fixed whirls as there are behind baffles, in bends, at tee pipes, etc. (Fig. 6B).

By a good construction of rectangular ducts with

rounded corners with $r = 1.5$ cm. at least, this practicable as shown in Fig. 6C.

Change of Direction for Flowing Stock

The mass forces dominate here, so for our stock flow we may take the water flow, provided the laminar- or boiling flow system does not have additive effects.

Bends. Bends are known as good mixers due to the two screw streams after these bends (Fig. 7A) (*12*). This, however, occurs only with round or nearly square bends. We have often very broad bends and there we do not have screw streams and mixing occurs according to the investigations of Nippert (*13*) (Fig. 7B).

To prevent the stream following the outside of the bend, all of the bends with short inner radius should be venturi bends according to Fig. 7C, as Busey (*14*) has given for air but which is also true for water and stock. An economical result is that for round and square pipes the resistance is much lower than that of a normal bend (10 to 40%).

Tee Pipes. These may be considered as double bends, and all that has been said for double bends is also applicable here.

Branch Pipes. When constructed in such a way that

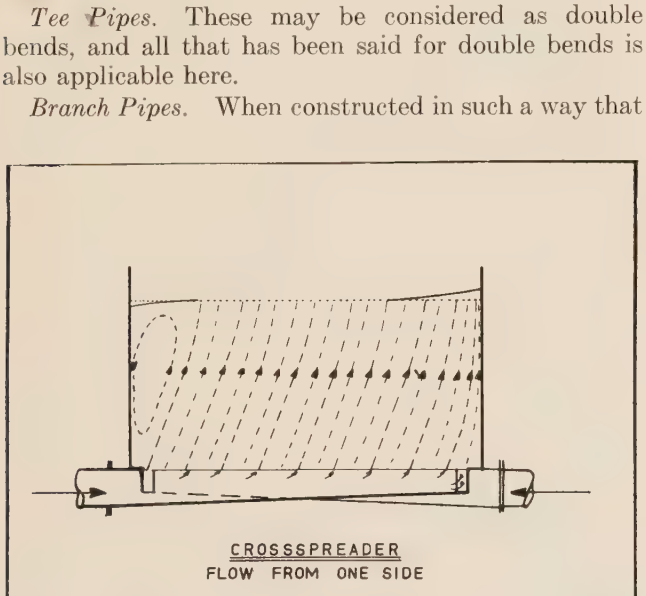

Fig. 9. Cross spreader

there are free or fixed vortices, the branch pipes will give trouble to the machine tender by accumulating fiber debris or slime on places where the flow velocity near a wall is low.

These branch pipes may be calculated as for water and still better tested by a model test. The influence of the stock on the flow is very small. The results are shown in Fig. 8 for a pipe with the approach pipe in the *same plane* as the branches and *perpendicular* to these. It is shown in the figure that the last one is not so stable as the first (*15*).

It is necessary to mention that the velocity distribu-

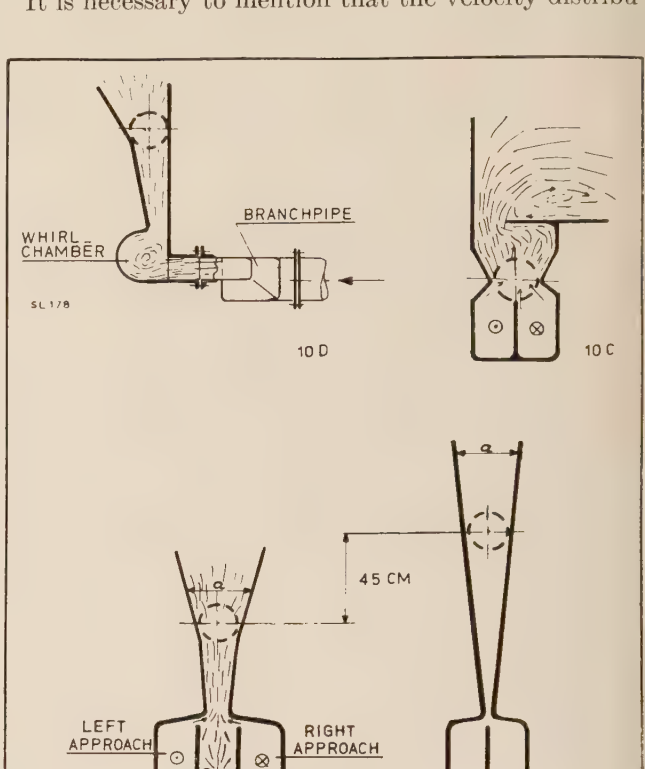

Fig. 10. Cross distributing systems and energy dissipation

tion in the branches is not equal, so the resistance of following bends will be different.

The pipes can be constructed as square pipes, provided the corners have a radius of at least 15 mm. to prevent thick water boundaries there, which are ideal places for slime to live in.

Cross Spreading. In contradiction to the branch pipe this is a continuous approach. It is not so easy to calculate the dimensions of such a pipe so that it will give a constant flow rate per unit width. This is due to the fact that the flow velocity in the upward canal is usually $2^1/_2$ times the velocity in the cross pipes.

The result of *one pipe* is a flow pattern according to Fig. 9A. With both pipes and holes at the end of the pipes for pressure escaping, it is possible to get a rather even flow rate with the maximum in the middle.

These measurements were made by a visual technique using a dimensionally correct model at the same Froude number as the full-scale plant. The model was found to accurately represent the full-scale equipment. By giving the bottoms of the pipes a slope, the cleaning up is made much easier.

The flow in the throat has, due to the diverging flow directions, a very strong turbulence which will diminish

during the upward flow in the widening canal. Evener rolls are still necessary, as the flow per unit is still not sufficiently equal to place a slice directly after the cross spreader.

To obtain a more equal flow rate, it is advisable to let the cross pipes not run in the direction of the upward

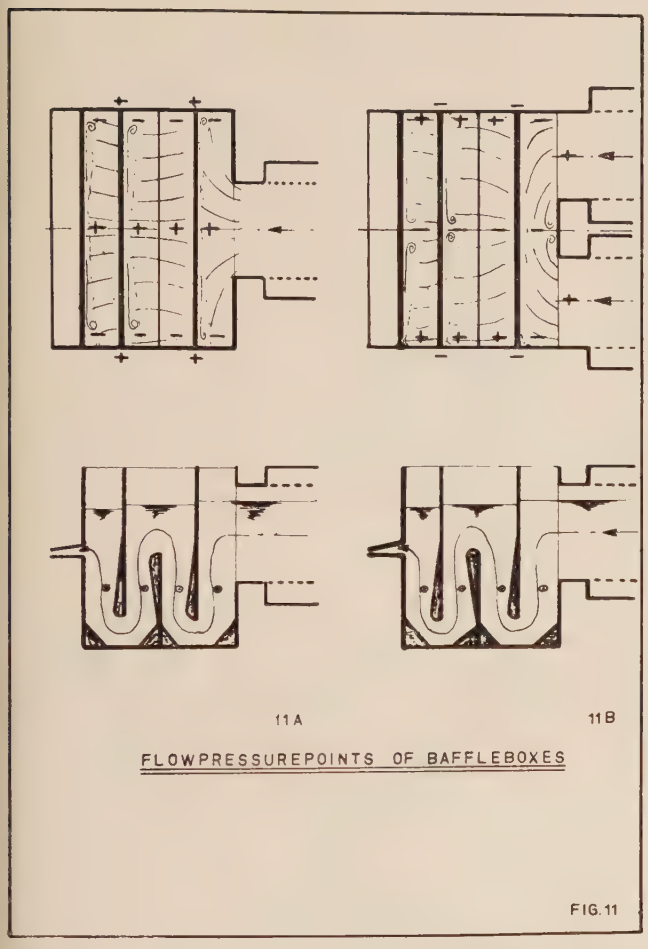

Fig. 11. Flow pressure points of baffle flowboxes

canal, but perpendicular to it, so that all jet energy is lost and a rather even flow goes upward through a much wider upward canal.

Flow Spreading. In contrast to cross spreading, with flow spreading there is the problem of the flow coming from one point, broadening to a jet of machine width.

The simplest way would be to have a flat pipe beginning round as screen mouth or pipe mouth and broadening to the slice jet. The greatest difficulty will be then that near the slice the jet is not parallel to the machine direction, which will give difficulties on the outer parts of the wire. Moreover the wall distance will become too small to make corrections. The resulting construction will be difficult to clean. So folding up is possible, open or closed, but for a good construction the bends must be venturi bends and the straight parts must be widened to gain distance between the walls. When this is done, the stream is more stable and with well-rounded corners there will be not much to clean. Most of the broadening must be done in the first part, so that the side walls are nearly parallel to the machine direction at the ends. Distributing rolls can do the rest. A result of an open flow spreader is shown in Fig. 8B. Flow spreading occurs also in a normal baffle box from one or more screen mouths to the width of the machine.

As the flowing direction is not parallel to the machine direction, there will be pressure maxima and minima on the surface from where the stock is flowing to the sides. Under the first baffle, the maxima are lying at the sides, at the surface after the baffle, in the middle again and so on.

As we have the pressure maximum on the slice surface in the middle, there will be a tendency to flow off to the sides and, by the secondary velocities, vortices may be generated in the corners near the sides where they do not give much harm.

In the case of two screens, the situation will be just the contrary, and there will be a minimum pressure at the surface in the middle of the slice. The stock has a tendency to flow from the slice to the middle and form vortices *there*. This makes a flowbox with one screen more stable than a flowbox with two or more screens, provided the streams from the screens are not brought together first before going downward under the baffle. That combining canal may be formed so that the pressure maximum will be in the middle of the approach flume, as can be seen in Fig. 11C.

Screen Plates and Screen Rolls

When we have to produce a turbulence, or we must

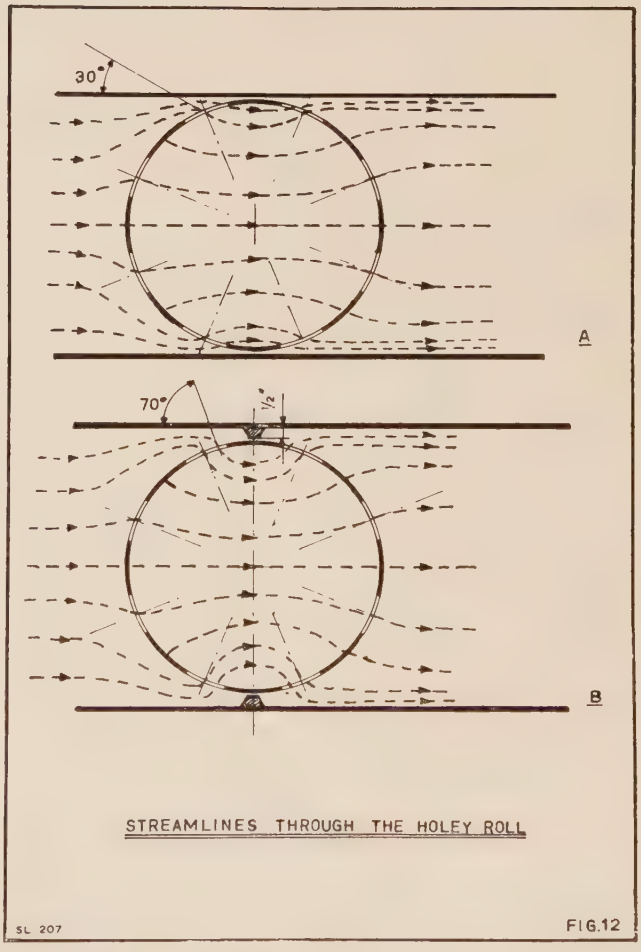

Fig. 12. Streamlines through a holey roll

reduce it, and also when we have to even out velocity variations, we may used screen plates or screen rolls. A roll is the same as a double screen plate, though the flowing direction behind the roll is quite different, for

due to the spreading flow direction, we will get a strong flow along the walls, so that it is possible to have a rather big angle between the walls, before the flows will not follow them as stated under "distributing rolls." Especially at the critical angles of $14^2/_3$ and 32°, we get a rather even velocity distribution. With smaller angles we will get a velocity minimum in the middle, so that a turbulence of high energy is generated as stated under "free canals." This is especially the case when there is a boiling flow system after the roll (*see* Heller curves)(Fig. 2). To have the best result, a roll must be as near as possible to the wall, say $^1/_8$ in. The difficulty then is that the direction of approach to the side holes is only about 30°, so that the fibers may be caught by the "thickness" of the roll. Therefore it is much better to have a $^3/_8$-in. strip on the wall, as is shown in Fig. 12B, by which the angle can be changed into 70°. In this way there is also not so much danger for fiber catching. Moreover it is possible to make the clearance between roll and strip quite equal over the whole length, even when the box is made of welded sheet. This is done by changing the height of the strip.

The possibility of producing or reducing the turbulence is due to the percentage of free openings in the roll. Baines and Peterson (*17*) have made interesting investigations for airflow, but in their investigations they had

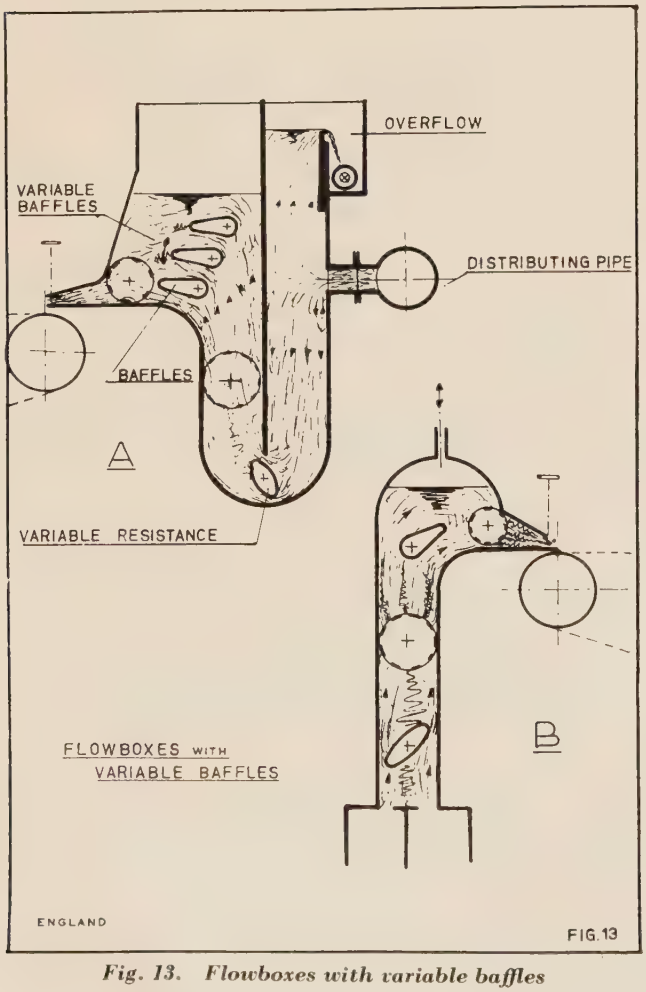

Fig. 13. Flowboxes with variable baffles

big mass forces and low viscosity, so that the results correlate very well for stock flow in this case.

The result is also, as Rouse (*18*) has stated, that a roll which is less than 50% open generates uncontrolled combinations of the outflowing jets of the roll. Therefore the last roll in the slice should be at least 52% open. When the resistance and velocity equalizing is rather low, we can take sometimes more rolls. The maximum number the author has seen is six!

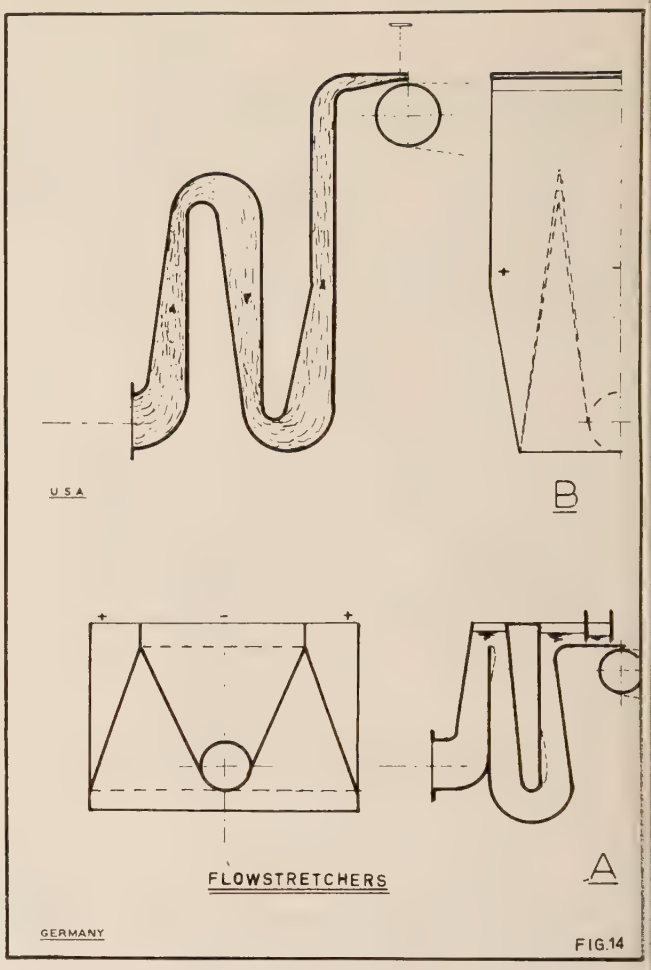

Fig. 14. Flow stretchers

Regarding the distance of the rolls, we must choose at least the length of the field necessary to generate the maximum intensity of the turbulence, which according to Baines and Peterson, Fig. 10, is for:

25% open.....	8–10 dam width (between the holes)
55% open.....	12–15 dam width

The distance of the rolls need not be much longer, for secondary streams may be generated by uneven approach flow. The resistance of a roll may be calculated as a double screen with water, without much failure, when we use the data for orifice plates according to DIN no. 1952 of Germany. The contraction factor is for a roll with:

m open = 35%	η = 0.646
40	0.661
45	0.677
50	0.696
55	0.717

So that the resistance of the roll will be:

$$p = \frac{2G}{\pi m\, \eta DL}$$

where

G = flow rate in kilograms per second
D = diameter of the roll in meters
L = length of the roll in meters
p = pressure difference of the roll in kilograms per square meter or millimeters water column

The resistance of two rolls in a tapered slice was calculated as 74.5 mm. water gage, the real resistance was 80 mm. water gage including the slice, so that the accuracy is sufficient. This resistance is right for a parallel canal, in other cases the influence of the canal must be calculated also. When we have, e.g., a baffle slice, Fig. 15A, according to DP 817680 (*19*), the resistance of two rolls of 200 mm. diam. with m open = 46% is practically zero, due to the more economical approach of the stock to the slice with rolls than without them.

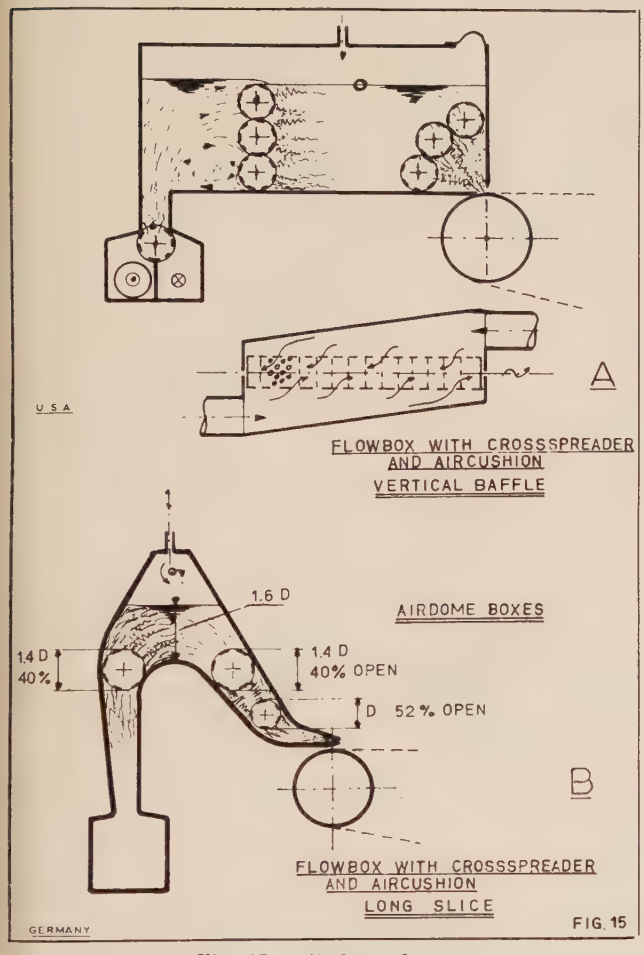

Fig. 15. Airdome boxes

The Slice

For high velocity it is advisable, to get a good flat jet from the slice, to use two evener rolls: no. 1 about 40% open to give the stock a high turbulence, and no. 2, about 52% open to equalize uncontrolled streams.

Distance of the roll shells from each other should be 12 to 15 times the dam width. Care should be taken that the supporting bearings are as small as possible to give no disturbance in the jet near the deckle strips. The shell must be drilled as far as possible to the ends to prevent retardation there, which will give the jet an outside flow direction.

The length of the slice must not be too short, for otherwise the macroturbulence of the roll will exist in the jet and only microturbulence is wanted. On the other side the slice cannot be too long, otherwise the angle between the plates becomes too small and we shall miss the stabilizing effect of the tapered slice while flocculation may occur. A practical length in Europe is:

$$L = \frac{V \times b}{12.5} \text{ or } \frac{V \times b}{13.6} \text{ in feet}$$

where

L = length from roll shell to slice end
V = machine velocity meters per minute or feet per minute
d = dam width between the holes in the last roll in meters or feet

This means that for a slice and perforated roll with or without air dome a critical speed will exist, beyond which an unstable jet will result. This gives good results with the long slice. With the vertical baffle wall there is the danger of getting a more unstable jet, as the distance from roll to slice is only 0.8 roll diameter. With two rolls 0.2 m. diam., 46% open, the distance L was 0.16 m. and the maximum velocity should there be 160 m. per min. At 200 m. per min. the jet was unstable (*20*) as could be seen by means of a stroboscope: drops flying from the tops of the waves.

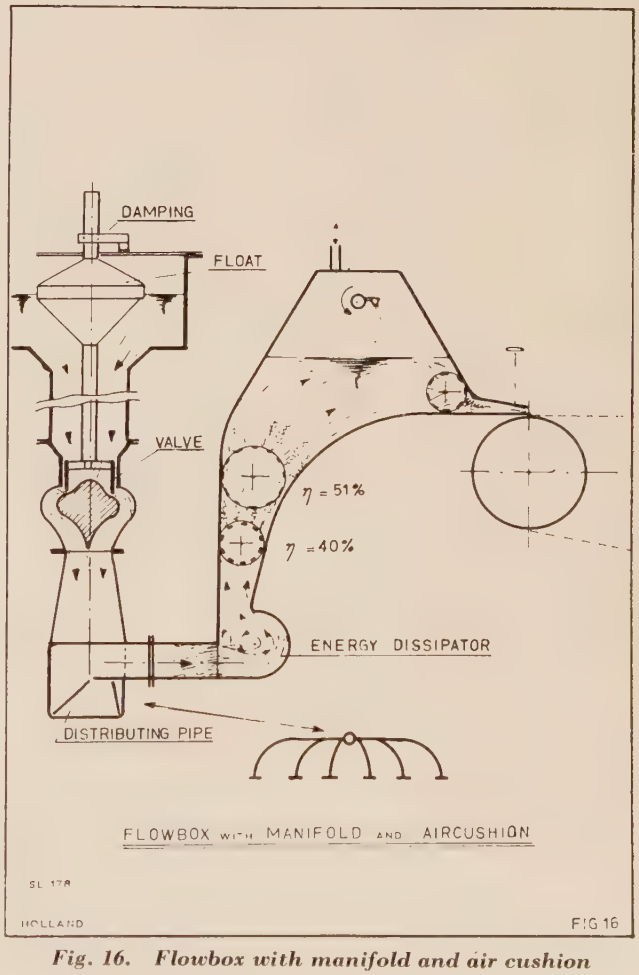

Fig. 16. Flowbox with manifold and air cushion

The direction of turning is not important. When a stock particle approaches the roll, it does not matter whether the hole approaches from the top or the bottom. The turning is only valuable for self cleaning.

Turning with a velocity of 0 to 200 r.p.m. and 100 mm. diam. made no difference on high grade bleached sulphite 40 S.-R., with 0 to 18 r.p.m. and 200 mm. diam. on newsprint either. Mostly 10 m. per min. is a good circumference velocity (*20*).

A REVIEW OF FLOWBOXES AND SLICES

We have been speaking about the principles used in design work, and in this section we will consider various designs with reference to some of the principles previously mentioned.

Baffle Boxes

In Fig. 11 we can see: (1) the oscillating possibility of the many water surfaces (*1*), (2) the whirls behind the baffles, which have been filled up here "fixed vortices"; (3) the dangers of the flow pressure points "flow spreading."

A rather new system is that the stock coming from an equally distributing branch pipe may pass along a movable baffle which gives an extra resistance of more than 2 ft. water gage (*see* Fig. 13A). An overflow gives a constant level on the approach side, but with the difficulty that variations in flow rate are brought to another point of the system, where they may do harm.

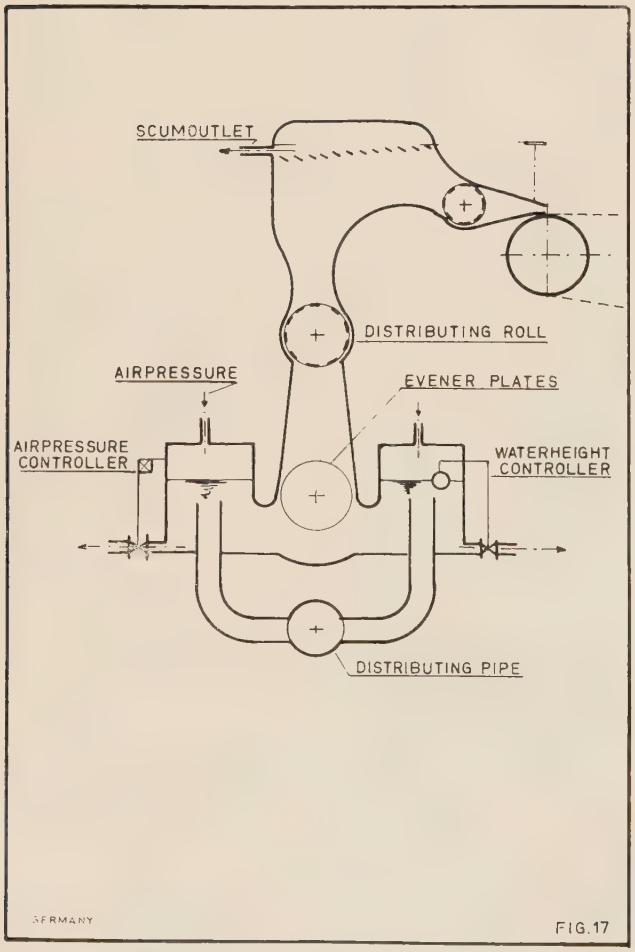

Fig. 17. Flowbox with double air dome

In the upper part will be a boiling flow "flow systems" generated by the turnable baffles, so the holey roll "screen plates and screen rolls" has the task to correct this, which seems to happen at 300 m. per sec. very well. The clogging of the upper baffle at lower speeds may give difficulties.

In Fig. 13B the details from Fig. 13A are used in a box with airdome, which may give the same result.

In Fig. 14A we see the flow spreader as an open construction. The same points, mentioned above, are

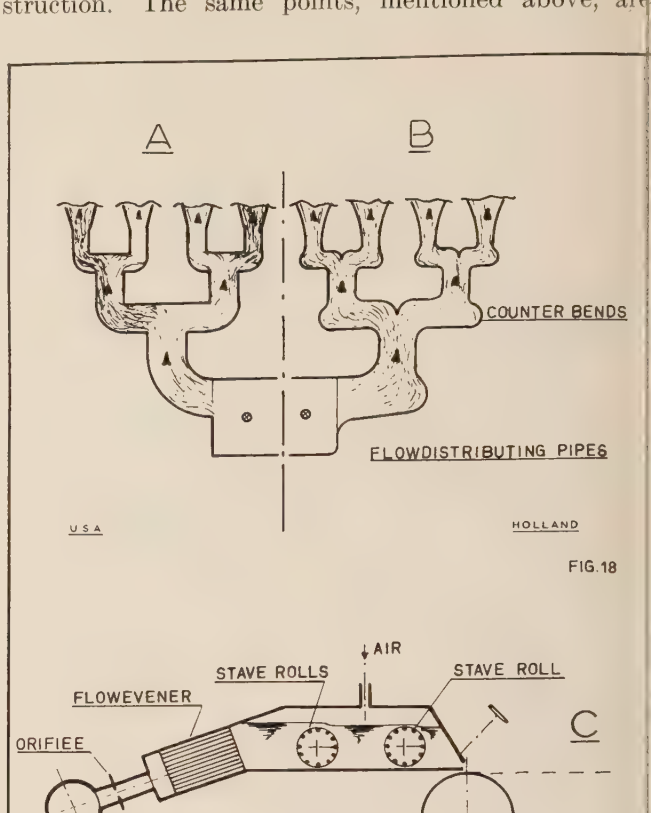

Fig. 18. Flow distributing pipes
Fig. 19. Flowbox with frozen flow

applicable here: oscillation, vortices, pressure points and boiling flow. For the pressure points a correction is possible by changing the canal width as Fig. 8B has shown.

Airdome Boxes

In Fig. 15 we see the airdome boxes. In Fig. 15A an even distribution from the crosspipe will be very difficult to get without a high flow rate near the sidewalls, as there does not seem to be a connection between the end of one canal and the beginning of the other, to allow the remaining flowrate at the end to bleed off to the beginning of the other. The vertical wall will give the possibility of generation of vortices. These vortices are dangerous with low stock height over the last distributor roll. The distance of the last distributor rolls up to the slice is even under the best conditions to small to give a smooth flow onto the wire at high velocities (*see* "the slice").

In Fig. 15B much attention has been paid to this last point so that the stock may lay very flat on the wire.

Figure 16 gives a construction for a smaller machine. A floating valve provides a nearly constant level in the

screen so that a flow rate change is brought direct to the flowbox.

The flow energy of the distributing branches is dissipated in a whirl chamber and from there the flow goes through two distributing rolls to the upper part, through which the narrowing flow is very stable and the

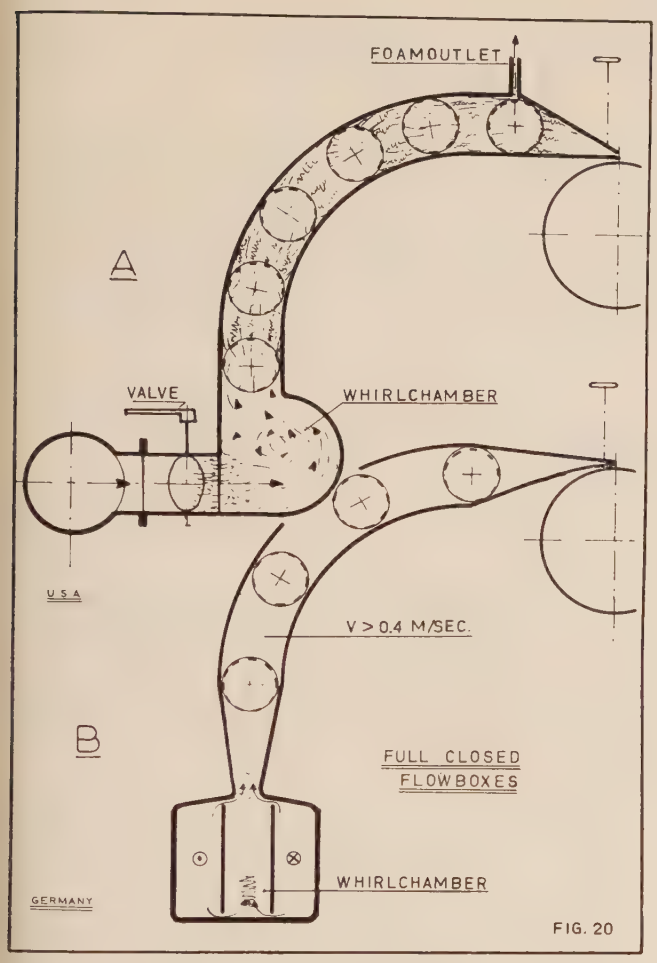

Fig. 20. Full closed flowboxes

result will be a newsprint sheet of 50 grams per sq. m. basis weight with 0.5% deviation.

Figure 17 is a design with the pressure chamber at the bottom and a scum outlet at the top. If the latter one is also filled with scum (air), an oscillating system is possible here due to the short circuit with low resistance. The result of the distributing pipe is so that turning evener plates is necessary. Fortunately a distributing roll is following to distort the streaks formed by the evener plates. The whole construction gives one the idea that it is unnecessarily complicated.

Figure 18 shows a distributor pipe (see Branch Pipes). After this pipe a broad canal is projected to the slice. The danger of the left side is, that with variable flow rate, a variable flow distribution occurs after every dividing point, due to the difference in flow pattern in the preceding bends, at different flow rates. The bigger the flow rate is, the more the flow will go to the outside. On the right side of the sketch the same construction is given, but with contrabends, so that a constant distribution for a wide flow range is obtained.

In Fig. 19 a flowbox is shown for giving a "frozen flow." This means that a velocity of 2 to 3 in. per sec. or less must be used to prevent boiling flow. Therefore the paper stock may not contain clay, etc., as this will settle down at the bottom. A narrowing canal will give a stable flow without this objection. Here stave rolls are used instead of holey rolls. It is right that these rolls give a turbulence with less energy. On the other side they don't give any correction in side direction and vortices will flow easier through them. When holey rolls with an opening percentage of more than 50% are used at sufficient distance from the slice, we will get a better result. This figure, it is learned, is not in exact accord with the boxes in use, and readers are referred to the relevant Canadian patent.

Closed Boxes

In Fig. 20 there are two constructions which are nearly the same. In the upper one a simple manifold is corrected with valves and the energy of the stream dissipated in a whirl chamber. The many holey rolls are necessary to make an even flow and to make the stock turbulent. Especially near the top this is necessary to avoid foam at the ceiling for the defoaming pipes are not able to take the foam totally away.

In Fig. 20B is the same construction, but now the machine tender has no valves with which to play. The number of evener rolls is reduced to four, since the flow velocity is so high that the boiling flow is avoided. The top plate of the nozzle is more upward than in A, so foam will more easily flow off. If the approach flow rate is very stable, this is the simplest flowbox you can have.

When holey rolls with strips along the walls, as in Fig. 12, are used, it is very well possible to make the box in plate with good corners and reinforced, especially where the rolls are inserted.

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The lecture regarding the above subject has been held on the initiative of the directors of Van Gelder Zonen N.V. by one of their employees as a token of appreciation for the help and sympathy they have always met with when visiting the United States and Canada.

Model Experiments of Sheet Formation on the Cylinder Wire

BÖRJE STEENBERG, JAN BERGSTRÖM, and R. I. KJENSJORD

Sheets have been made on the wire of a stationary probe with the stock flowing past the wire. The stock velocity and freeness, consistency and making head were varied and the influence of these papermaking variables on the drainage and sheetmaking rates and on the sheet properties have been studied. The drainage rate is determined by a specific drainage resistance of the sheet formed, and a simple method for estimating this resistance is given. A considerable washing off effect is demonstrated, causing a deviation from proportionality between basis weight and drained volume of water. This effect is pronounced at low stock freeness and low making head. A fiber fractionation takes place as the sheet is being formed, and the higher the rate of flow of stock relative to the wire, the lower is the average fiber length and bulk of the sheet. Thus, the consistency and freeness of the stock in the vat increases with the distance from the inlet, and an overflow is necessary in direct-flow vats. In a counterflow vat a steady state is reached without such arrangement. The possibility of influencing the sheet properties by varying the making head during the formation process is mentioned.

THERE is only meager information available about the fundamentals of sheet formation on the wire of a cylinder paper machine.

A mathematical analysis of the problem by Ishihara (*1*) is based on a modification of Poiseuille's law. In his treatment the relative motion between the stock in the vat and the wire is not considered. It is assumed that the stock concentration is constant throughout the vat and the basis weight of the sheet is assumed to be directly proportional to the drained volume of water. Although good agreement between measured and predicted basis weights is reported, the value of the treatment may be questioned, because of the approximations mentioned above.

Tolskij (*2*) has given an equation for the rate of drainage along the wire, but has made an obvious slip in the application of the Poiseuille and Bernouille laws. No experimental evidence supporting the theory is reported.

Hormann (*3*) discusses the general characteristics of cylinder machine formation in a qualitative way, making the assumption that the basis weight increases in proportion to the volume of water drained through the wire.

Gough (*4*) expresses a firmly stated opinion that at small heads a very appreciable amount of the fibers deposited on the wire is frequently washed off and quotes information given in Goldsmith's paper in 1938 (*5*).

Recently Goldsmith and co-workers (*6*) have considered the existence of a washing-off effect as a matter of conjecture.

Because of the difficulty of making actual observations and experiments on a vat machine, model experiments should be of special value. Such experiments have recently been described by Payne and Guthrie (*7*). The technique employed in their investigation does not, however, allow a study of the effect of the relative speed between stock and wire on the sheetmaking process and on the properties of the sheet formed.

The model experiments to be described rest on the following basic ideas.

Different constant making heads should be employed. The zones of increasing the decreasing head were considered to be of secondary interest and were not the subject of the study.

The relative motion of the wire and the stock should be controllable within the range of general practical interest. This was to be accomplished by having a stationary wire and the stock flowing past the wire.

The sheet was to be formed on a wire placed horizontally, with the formation proceeding from below.

The sheet formation should take place from a suspension so large in volume that there was no measurable change in its consistency during the formation of a few sheets.

The rate of substance increase and the corresponding volumes of drained water should be measurable as well as the maximum number of physical and mechanical properties of the produced sheet.

The essential part of the employed apparatus, the probe (Fig. 1), was designed after some experimentation. It is essentially an inverted small sheet machine. The dimensions of the probe (see Fig. 1) were chosen small in order to obtain uniform sheet formation and still to allow sufficiently accurate determination of sheet properties. The probe was fitted with a 100-mesh wire and had a rubber tube, acting as a siphon, connected to it.

The probe was developed during preliminary experiments on sheet formation by dipping it, filled with water, into a beaker with a stock suspension slightly stirred to prevent sedimentation. By changing the position of the siphon's lower end in relation to the liquid level in the beaker different making heads were obtained.

In order to be able to make sufficiently accurate measurements of volume and time during the sheet forming process even at large heads, the cross-section area of the siphon (A_1) was chosen much smaller than the area of the wire (A_0). Thus, at a given head h and with pure water in the system the rate of flow through the wire of the probe will be $q = (A_1/A_0) \times \sqrt{2gh}$, i.e., A_0/A_1, times lower than in a cylinder machine at the same making head. In the first approximation therefore, the forming process on the probe would be A_0/A_1 times slower than on a cylinder machine, other

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conditions being the same. In the experiments to be reported $A_0/A_1 = 78$.

Due to the low rates of drainage and sheet build-up in the model experiments, the sheets formed will have a more closed structure than sheets formed on a cylinder wire from the same stock employing the same making

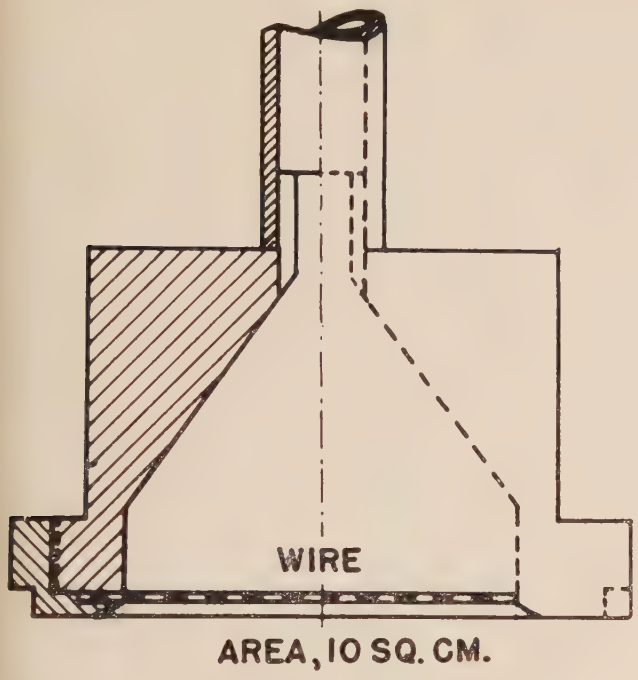

Fig. 1. Probe

head. A direct comparison of properties of probe sheets and machine-made sheets should be avoided. Nevertheless, the effects of varying sheetmaking conditions as found in the model experiments is thought to reflect corresponding effects in machine operation.

In the main experiments the probe was attached to to the stock system as shown in Fig. 2. The stock was drawn from a chest by a small centrifugal pump driven by a variable speed motor through a flow spreader into a box made of Lucite. The top of this box was horizontal, the bottom sloping upward. The end of the box was open and the stock returned to the chest. In the top of the box the probe could be placed in several positions with the wire flush with the inside of the box top. Pressure tubes allowed determination of the static pressure and the velocity of the flow in all possible positions of the probe. Before starting an experiment, the probe and its attached rubber tube were filled with water. The making head was determined by the difference in height of the wire and the free end of the siphon plus the static pressure, as measured by a pressure tube at right angles to the flow.

In a cylinder machine the true making head is the difference in level between the stock in the vat and the white water inside the cylinder, subtracted by $1/2g \times$ [stock velocity in vat]^2, where g is acceleration due to gravity.

The reported experiments were carried out with unbleached sulphite pulp at 18 to 68° S.-R. The stock consistency was varied between 0.34 and 3.4 grams per liter, the effective pressure between 30 and 200 mm. water column, and the velocity of flow between 0.05 and 0.5 meter per sec. Symbols are explained in Table I.

Table I

n	= Experiment number
v	= Stock velocity past wire, meters per second
h	= Effective head, millimeters water
t	= Drainage time, seconds
Q	= Volume of filtrate per unit area
W	= Basis weight (moisture-free) grams per square meter
c	= Stock consistency, grams per liter
D	= Sheet density, grams per cubic centimeter
G	= Porosity, Gurley, seconds per 100 ml.
BM	= Breaking length, machine direction, meters
BC	= Breaking length, cross direction, meters

The experimental results can be plotted in a great number of different ways, and it has been thought of value for further discussions to publish them in full. Table II contains the results of the first part of the investigation in which only drainage and sheetmaking rates were studied under different conditions. The second part of the investigation also included studies of the physical and mechanical properties of the sheets formed on the probe under different conditions. These results are reported in Table III.

In the following, the results will be discussed with the aid of generalized curves. An attempt has also been made to establish a mathematical expression for drainage-time curves as recorded in the probe experiments.

DRAINAGE AND SHEET FORMATION AS FUNCTIONS OF SHEETMAKING VARIABLES

Although the rate of drainage of pure water through the wire is constant, the rate of drainage of stock, at the start identical with that of pure water, will decrease with time.

As soon as the sheet starts to build up there is a pressure drop across the sheet and the rate of drainage will decrease.

During the preliminary static experiments it was possible to verify the validity of the usual filtration equation (1) in this sheetforming process:

$$\Delta P = R\eta W \frac{dQ}{dt} \qquad (1)$$

In this equation, which is based on a simplification of Poiseuille's law, ΔP is the pressure drop across a sheet of basis weight W when the rate of flow per unit area is dQ/dt, and R is the specific resistance to flow of

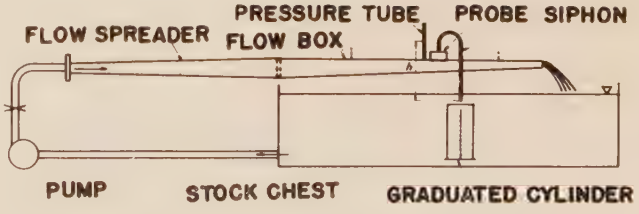

Fig. 2. Experimental setup for model experiments

the filter bed. The viscosity of the liquid is η. With a pressure drop ΔP over the sheet a making head of h will give a rate of flow through the sheet:

$$\frac{dQ}{dt} = \frac{A_1}{A_0}\sqrt{2g(h - \Delta P/\rho g)} \qquad (2)$$

where ρ denotes the density of the liquid.

Table II. Summary of Sheetmaking Conditions

Unbleached sulphite

n	v	h	t	Q	W
	A. 18° S.R., c = 0.53 Gram per Liter				
1	0.3	30	12	5	7.5
		30	25	10	...
		30	73	20	24.5
2	0.3	60	7	5	...
		60	23	15	33
		60	61.5	30	51
3	0.3	120	8	10	28
		120	25	25	64.5
		120	55	40	83
4	0.1	60	7	5	...
		60	21	15	49.5
		60	49	30	102
5	0.1	120	4	5	...
		120	13	15	62.5
		120	32	30	125
6	0.1	200	6	10	47
		200	13.5	20	...
		200	21.5	30	135
7	0.035	60	12	10	...
		60	27	20	...
		60	47	30	...
		60	71.5	40	...
	B. 68° S.R., c = 0.42 Gram per Liter				
8	0.3	30	5	2.5	...
		30	15	5	...
		30	66.5	7.5	...
		30	110	10	5
9	0.3	60	7	5	12.5
		60	16.5	7.5	...
		60	58.5	10	18
		60	152	12.5	18.5
10	0.3	120	5	5	...
		120	9	7.5	...
		120	22	10	25
11	0.3	200	3	5	...
		200	5	7.5	...
		200	10	10	28.5
12	0.1	30	5	2.5	...
		30	12	5	12.5
		30	21.5	7.5	...
		30	43.5	10	25
13	0.1	60	3	2.5	...
		60	7	5	16
		60	22	10	30
		60	68	15	40
14	0.1	120	2	2.5	...
		120	4.5	5	17
		120	12	10	35
		120	33	15	45
15	0.1	200	1.5	2.5	...
		200	6	7.5	26
		200	10	10	...
		200	26.5	15	47.5
		200	92	22.5	62
16	0.05	60	6.5	5	...
		60	18.5	10	27.5
		60	43	15	39
	C. 68° S.R., c = 1.3 Grams per Liter				
17	0.3	60	4.5	2.5	14.5
		60	23	4	20
		60	47	5	...
		60	164	6.5	22
18	0.3	200	2	2.5	...
		200	10	5	25.5
		200	63.5	7.5	...
		200	182	10	39
19	0.1	60	4	2.5	22
		60	15.5	5	38
		60	65	7.5	...
		60	180	10	45
20	0.1	200	1.5	2.5	...
		200	4	5	50.5
		200	16.5	7.5	...
		200	37	10	70
		200	144	15	78
	D. 68° S.R., c = 2.3 Grams per Liter				
21	0.5	30	8.5	0.5	...
		30	50	1.5	...
		30	125	2	...
22	0.5	200	1.4	1.7	25
		200	3.5	2.5	29
		200	30	4	...
		200	136	5.5	35.5
23	0.3	60	1.5	1	18.5
		60	5	2	...
		60	13.5	2.5	20
		60	73	4	25
24	0.3	200	1.7	2	37
		200	5	3	...
		200	14	4	46
		200	73	6	...
		200	138	7	49.5
25	0.2	30	3	1	...
		30	6.5	1.5	9.5
		30	20.5	2.5	12.5
		30	96	4	...
		30	208	5	17.5
26	0.2	200	2.5	2.5	40.5
		200	19	5	53
		200	54	7	...
		200	92	8	57
27	0.1	30	3	1	...
		30	7.5	2	16
		30	21.5	3.5	21
		30	59	5	...
		30	103	6.2	25
28	0.1	60	4	2	33.5
		60	13.5	4	...
		60	24	5	44
		60	65	7	...
		60	153	9	49
29	0.1	200	2.5	2.5	47
		200	7.5	4	...
		200	13	5	59.5
		200	43.5	8	...
		200	84.5	10	74
30	0.05	30	3.5	1	...
		30	21.5	3.5	20.5
		30	78.5	5.2	24
31	0.05	200	2	2.5	51.5
		200	10	5	80
		200	27	8	...
		200	45.5	10	101

At the start of the sheet formation process the substance of the sheet increases in proportion to the drained quantity of water at a rate determined by the fiber content of the stock. Assuming that, on drainage, all fibers are deposited on the wire the following relation exists between basis weight and drained volume:

$$W = cQ \tag{3}$$

where c denotes the stock consistency. After substitution of equations (1) and (3) in equation (2) the latter is easily integrated when h and R are constant. The volume-time relation can be written

$$2a\frac{A_1}{A_0}\sqrt{2gh}\cdot t = aQ(aQ + \sqrt{1 + a^2Q^2}) + \log\,(aQ + \sqrt{1 + a^2Q^2}) \tag{4}$$

$$a = \frac{A_1}{A_0}\cdot\frac{R\eta c}{\rho\sqrt{2\,gh}} \tag{5}$$

When formation has continued for some time, the sheet substance does not increase in proportion to the quantity of drained water and equation (3) is not valid during the latter part of the sheetforming process. This was confirmed at all rates of flow of stock and was found even in stationary experiments (no flow of stock past the wire). Nevertheless, the experimental results, Fig. 3, show that the total drainage resistance $\Delta P/(\eta dQ/dt)$, increases in the same way as if equation (3) was generally applicable. This seems to be the case as long as there is still noticeable increase in basis weight. (When there is no further deposition of fibers the drainage characteristics are of less interest.)

Table III. Summary of Sheetmaking Conditions and Sheet Properties

Unbleached sulphite, 40° S.R.

n	v	h	t	Q	W	D	G	BM	BC
				A. c = 0.34 Gram per Liter					
32	0.05	30	132.0	25	45	0.49	31	7260	
33	0.05	60	25.0	15	39	0.44	8.2	6050	
34	0.05	120	8.4	10	26	0.43	1.8		
		120	...	15	38	0.46	7.7	6620	
35	0.05	200	6.1	10	28	0.41	2.0		
		200	10.2	15	40	0.47	6.8	6050	
		200	14.9	20	53	0.47	12	...	
		200	22.2	25	68	0.49	16	...	3330
		200	51.5	40	94	0.46	43	...	3480
36	0.1	60	27.0	15	39	0.51	7.6	6710	
		60	65.7	25	57	0.49	25	7930	
37	0.1	120	15.2	15	46	0.49	6.0	...	2850
		120	36.3	25	69	0.52	26	8000	
38	0.1	200	6.4	10	32	0.46	3.8	...	(1050)
		200	10.6	15	48	0.48	7.8	6270	
		200	16.3	20	60	0.49	12	6560	
		200	23.6	25	67	0.51	18	...	3220
39	0.3	60	152.3	18	20	0.61	122		
40	0.3	120	9.3	16	22	0.48	5.9		
		120	36.2	20	34	0.55	66	4530	
41	0.3	200	3.2	5	15	0.39	1		
		200	6.5	10	27	0.44	5.4	...	1760
		200	11.6	15	37	0.48	12		
		200	39.6	25	49	0.59	80	6380	
		200	91.4	30	53	0.63	331	...	2520
42	0.5	200	2.9	5	12	0.38			
		200	6.7	10	20	0.48	3.4	3600	
		200	47.1	22.5	29	0.63	67	...	1680
				B. c = 1.4 Grams per Liter					
43	0.1	200	1.7	2.5	34	0.52	11	...	2950
		200	3.8	5	63	0.52	20	...	3420
		200	6.5	7.5					
		200	10.1	10	86	0.53	42	6920	
		200	23.8	15	122	0.53	74	8370	
44	0.3	200	1.8	2.5	36	0.50	17	...	2780
		200	4.2	5	52	0.54	44	6580	
		200	9.4	7.5	58	0.56	81	8140	
		200	22.8	10	62	0.63	325	...	3400
		200	132.8	14.5	73	0.68	3600	7800	
45	0.5	200	4.5	5	38	0.59	53	...	2630
		200	14.5	7.5	43	0.66	116	...	2690
		200	68.8	10	50	0.71	1320	6670	
				C. c = 3.2 Grams per Liter					
46	0.1	200	1.3	2.3	53	0.49	13	...	3050
		200	1.4	2.4	55	0.56	18	...	3420
		200	3.4	3.9	120	0.51	41	...	4000
		200	5.7	5.0	134	0.49	56		
		200	10.7	6.9	159	0.49	87	4840	
47	0.2	200	1.5	2.2	49	0.47	15	7130	
		200	3.0	3.5	83	0.53	39	...	4150
		200	6.5	5.0	100	0.55	75		
		200	10.5	6.1	101	0.54	120	7140	
		200	20.5	8.0	118	0.53	196	...	4170
		200	44.5	10.0	114	0.59	894	...	4230
18	0.3	200	1.9	2.4	57	0.46	26	...	3780
		200	4.4	4.1	72	0.55	60	7460	
		200	10.6	5.6	78	0.57	184	8400	
		200	30.5	7.2	80	0.56	720	...	3580
		200	60.4	8.2	88	0.59	1800	8000	
		200	102.6	9.0	83	0.59	2990	...	4450
				D. c = 3.4 Grams per Liter					
49	0.1	200	3.2	3.0	107	0.58	59	3100	
		200	4.1	3.9	128	0.50	81	...	3950
		200	4.9	4.5	110	0.57	74	...	3920
		200	7.5	5.2	169	0.49	103	3600	
		200	10.7	6.4	162	0.55	142	...	4300
		200	13.2	7.1	157	0.52	130	4000	
50	0.3	200	2.4	2.7	59	0.50	22	9240	
		200	2.8	2.8	61	0.54	31	...	3840
		200	3.4	3.2	66	0.54	31		
		200	4.3	3.5	75	0.55	53	7760	
		200	5.2	3.6	69	0.56	111		
		200	7.6	4.7	82	0.53	87	7900	
		200	10.5	5.1	82	0.59	197	...	3970
51	0.5	200	2.8	2.5	48	0.55	30		
		200	3.3	3.1	50	0.59	80	...	3280
		200	5.6	3.5	52	0.63	115	5600	
		200	7.9	4.0	57	0.64	191	...	3350
		200	10.6	4.4	57	0.58	195	6680	

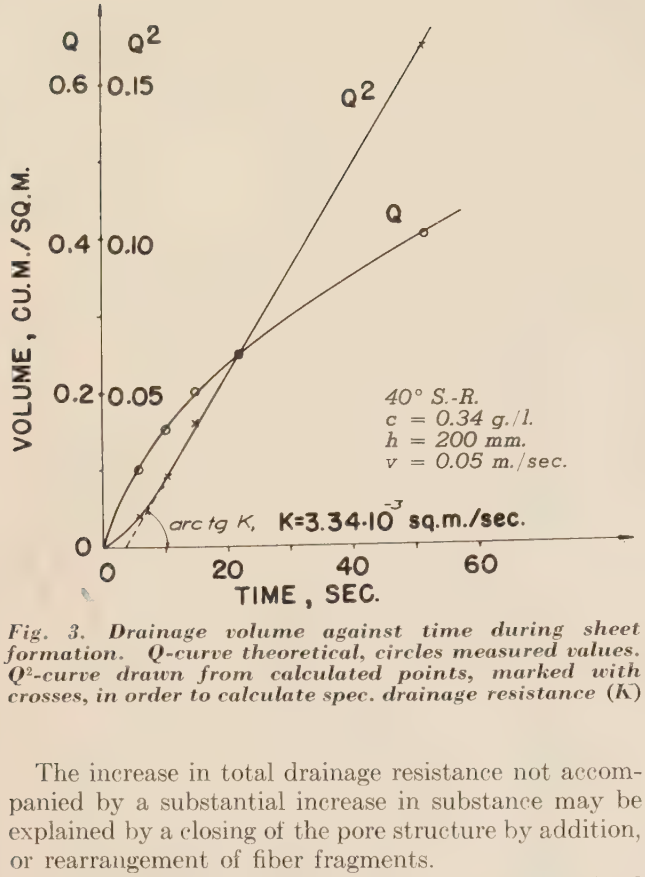

Fig. 3. Drainage volume against time during sheet formation. Q-curve theoretical, circles measured values. Q^2-curve drawn from calculated points, marked with crosses, in order to calculate spec. drainage resistance (K)

The increase in total drainage resistance not accompanied by a substantial increase in substance may be explained by a closing of the pore structure by addition, or rearrangement of fiber fragments.

The specific drainage resistance R can be determined in a very simple way from an experimental volume-time relationship by plotting the $Q^2 - t$ curve, which becomes a straight line when $aQ>1$. The slope K of the straight part of that curve is approximately

$$K = 1.9 \cdot \frac{\rho g h}{R \eta c} \qquad (6)$$

In this expression R is the only unknown quantity.

In static experiments the volume-time relationships are in accordance with the theory derived on the basis of a constant specific drainage resistance. With the stock flowing past the wire the same accordance is generally found during the major part of the sheet-forming period. At higher stock velocities, the specific

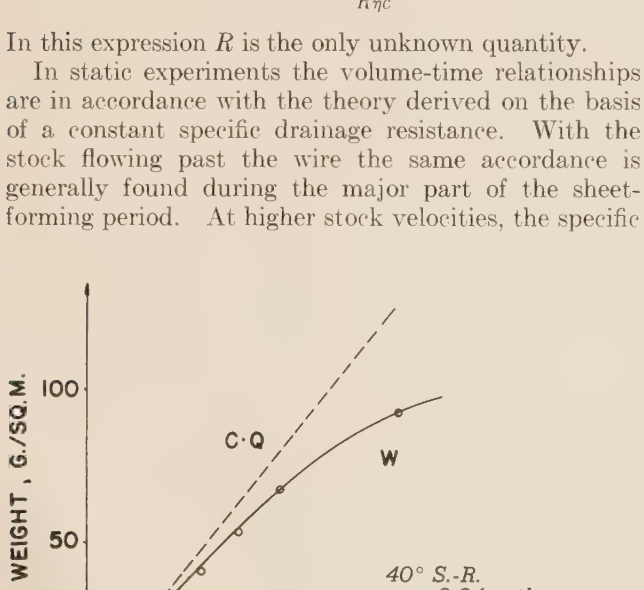

Fig. 4. Sheet formation on probe. Basis weight as function of drainage volume.—Same experiment as in Fig. 3

resistance usually increases slightly toward the end of the formation process. In Fig. 3 is shown an example of a drainage volume-time diagram obtained with a stock velocity of $v = 0.05$ meter per sec. From the slope of the straight part of the $Q^2 - t$ curve the drainage resistance R is determined. Using the Giorgi system of units in this example, we find the slope $K = 3.34 \times 10^{-3}$ sq. meters per sec. Hence

$$R = \frac{1.9 \times \rho g h}{K c \eta} = \frac{1.9 \times 10^3 \times 9.8 \times 0.2}{3.34 \times 10^{-3} \times 0.34 \times 10^{-3}} = 3.3 \times 10^9 \text{ m./kg}$$

where $\eta = 10^{-3}$ kg. per meter at 20°C.

The volume-time curve drawn in Fig. 3 is calculated from equation (4), using the proper value of a, in this case 7.2 $m.^{-1}$. This curve fits the experimental points very well, although there is a pronounced deviation from proportionality between basis weight and drained volume, as seen in Fig. 4.

The volume-time and the basis weight-volume relations together determine the increase in sheet substance as a function of time. As both these relations are far from linear, the deviation from constant rate of basis

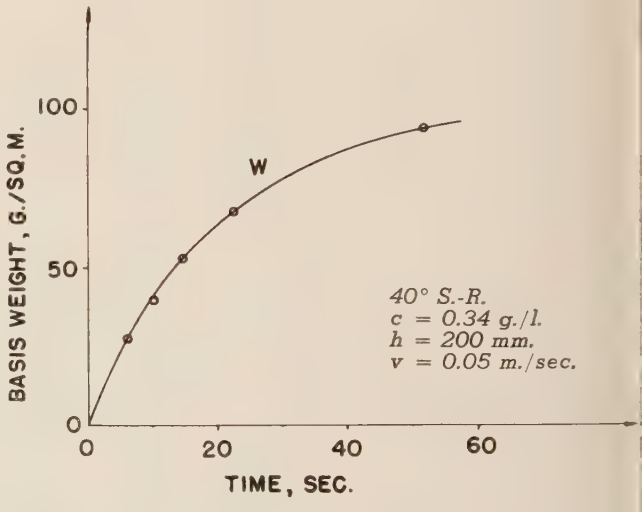

Fig. 5. Sheet formation on probe. Basis weight as function of forming time.—Same experiment as in Figs. 3 and

weight increase is very pronounced as seen from the same experiments in Fig. 5.

From experiments carried out at different consistencies, it is found, as could be expected, that under otherwise constant conditions the rate of drainage is considerably higher at a lower consistency. The deviation from linear conditions is most pronounced in systems with higher consistencies when the original substance increase is more rapid.

The curves representing basis weight as a function of forming time at varying stock consistencies will because of the above-mentioned, diverge rather widely after a short time but eventually get closer again because substance increase levels off much more rapidly at higher than at lower consistencies (Fig. 6).

If the experimental results are viewed from the standpoint of varying velocities of stock flow relative to the wire, it is found that the rate of drainage is higher at lower velocities of flow. Conversely, the resistance to

drainage is higher for a sheet of specified substance if formed at higher relative rates of flow of stock. If the relation between basis weight formed and the corresponding volume of drained water is studied, it will be found that the deviations from linear behavior occur at larger volumes of drained water when the rate of flow

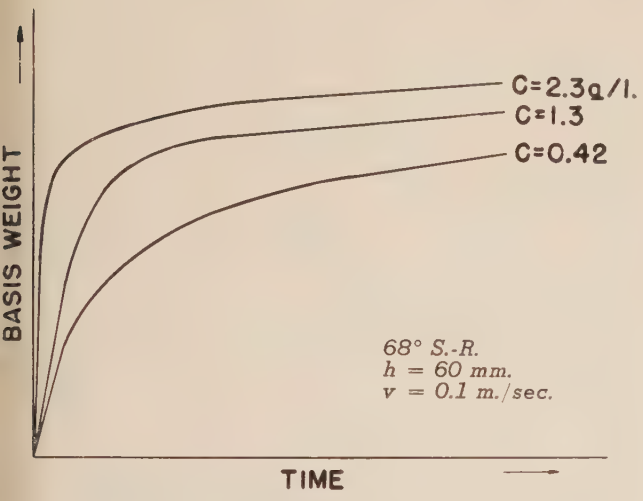

Fig. 6. Basis weight-time curves for sheet formation on probe at different stock consistencies

is smallest (Fig. 7). However, even when the suspension is stationary against the wire, such a deviation will eventually occur. At higher velocities of flow, drainage soon proceeds without increase in substance.

The above information implies that the highest basis weight obtainable is reached at the lowest rates of flow passing the wire.

Comparing the results obtained with the same pulp beaten in different ways, it is found that the increase in basis weight against time is faster at a lower Schopper-Riegler figure than at a higher, and also that a higher basis weight is obtainable with a free stock (Fig. 8).

The difference in rate of substance increase using pulp beaten to different extents was insignificant at low basis weight, but increased with increasing basis weights. The deviation from linear relations between basis weight and drained water was most pronounced when using a highly beaten pulp.

In Fig. 9 the drainage resistance is shown as a function of freeness and making head.

The results of the above-mentioned experiments can be summarized as follows:

The rate of drainage is determined by the making head and the pressure drop across the sheet formed. The latter is proportional to the stock consistency and to the specific resistance of the deposited fiber layer. This parameter is, apart from the obvious influence of the stock freeness, influenced by the papermaking variables as follows:

Increasing velocity of stock: increasing resistance
Increasing consistency of stock: decreasing resistance
Increasing making head: increasing resistance

The experiments are considered to have conclusively demonstrated the existence of a considerable "washing off" effect which cannot even be offset in an ideal direct-flow vat.

The deviation from proportionality between basis weight and quantity of drained water is increased by low freeness of the stock, high velocity of stock relative to the wire, high stock consistency, and a low making head.

QUALITATIVE PROPERTIES OF SHEETS

Further information regarding the process of sheet formation is obtained from studies of the physical and mechanical properties of the sheets formed on the probe under different conditions.

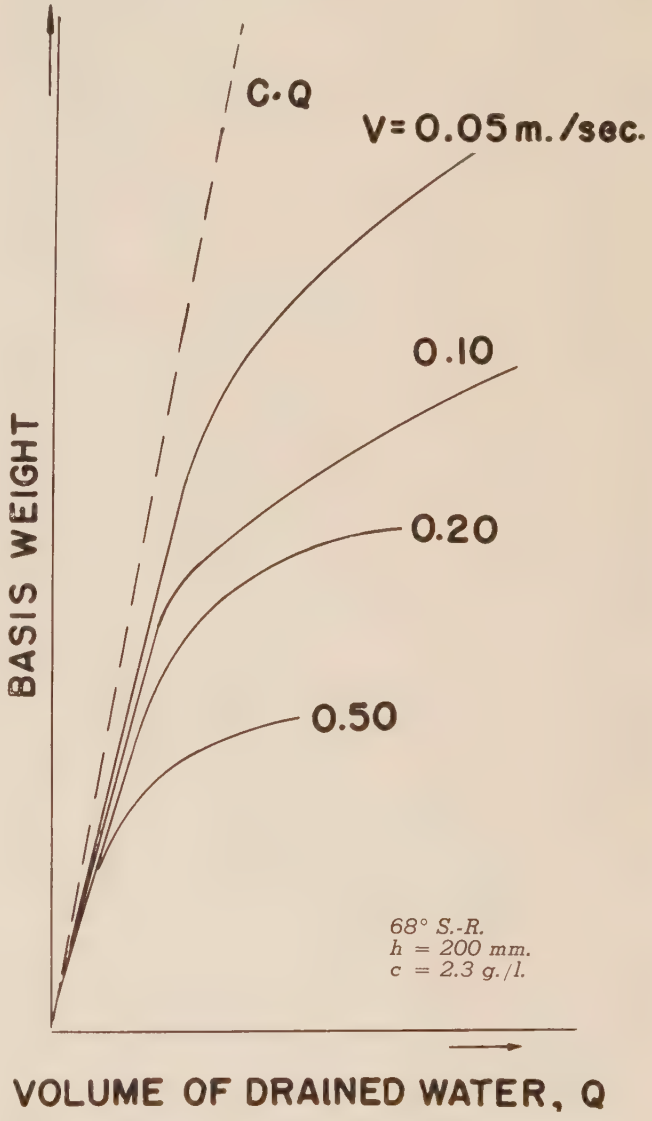

Fig. 7. Basis weight against volume of drained water during sheet formation on probe at different rates of flow (V) past the wire

It was found that the fiber length frequency diagram of the sheet was influenced by the rate of flow passing the wire. At 0.1 meter per sec. velocity the average fiber length was 1.67 mm. in a sheet of 50 grams per sq. meter when formed from a certain fiber suspension. When the velocity of flow was 0.3 meter per sec. relative to the wire, the same fiber suspension yielded a sheet with only 1.33 mm. average fiber length. The

fiber length distribution in the two sheets is shown in Fig. 10.

By a number of different tests it was found that the sheet was made up of material of different composition than that of the bulk stock. At a high rate of flow relative to the probe surface, stock slowly extracted by the probe without wire had significantly different properties from that of the bulk stock. This difference in properties could be observed for instance from the fact that standard laboratory sheets made from the bulk stock and the stock extracted via the probe had different bulk and Gurley porosity. This factionation is probably caused by inertia effects since there is less

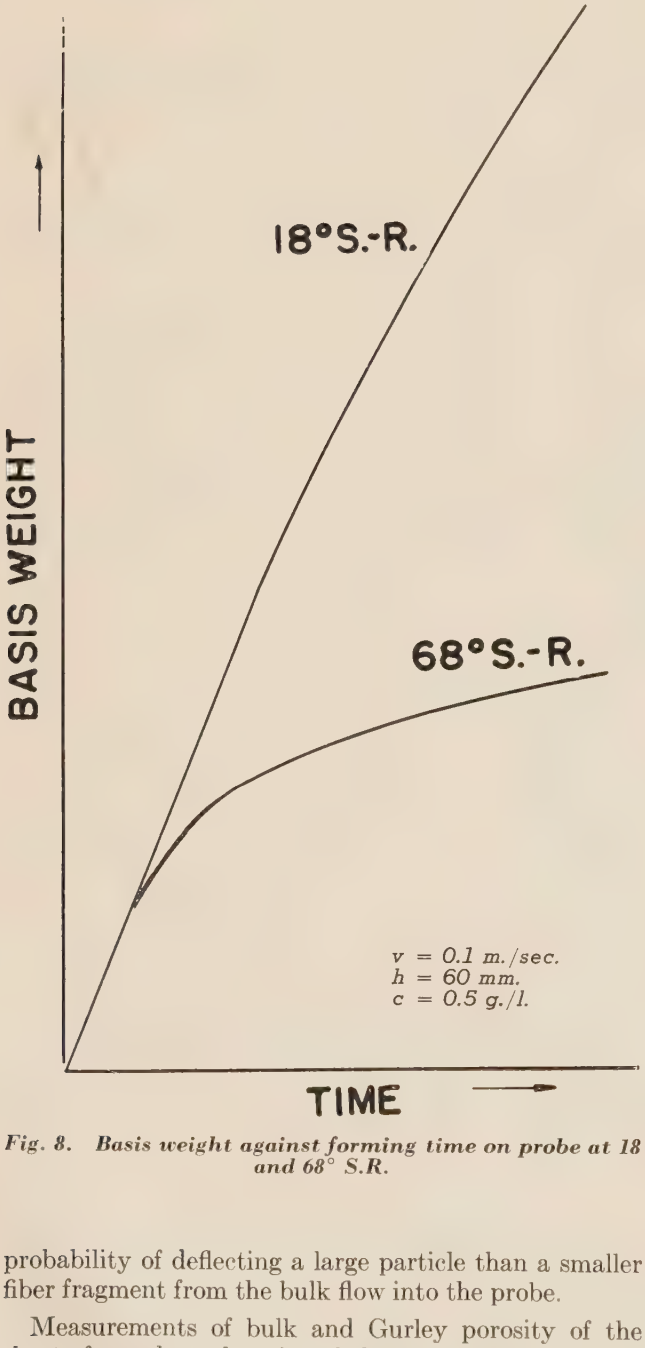

Fig. 8. Basis weight against forming time on probe at 18 and 68° S.R.

probability of deflecting a large particle than a smaller fiber fragment from the bulk flow into the probe.

Measurements of bulk and Gurley porosity of the sheets formed on the wire of the probe gave the same general picture.

The sheets were pressed and dried under standard laboratory conditions for handsheets. It was found that under otherwise identical conditions and for equa substance a sheet formed at the higher making hea had higher bulk and porosity. At high making head the sheet is formed more rapidly and the difference i

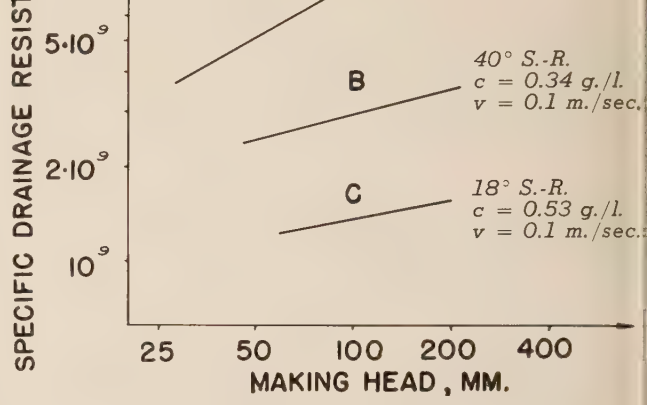

Fig. 9. Specific drainage resistance (R) of sheet formed o probe as a function of making head (h) at different free ness of stock

sheet composition from that of the bulk stock is smallest (Fig. 11).

The influence of different rates of flow of the stoc relative to the wire on sheet bulk and porosity is ver pronounced (Fig. 12). The higher the rate of flo relative to the wire the lower is the bulk and the po rosity. Under like sheetmaking conditions the loga rithm of porosity in Gurley seconds increases approxi mately linearly against basis weight.

The extreme variability in porosity caused by diffe ent sheetmaking conditions is perhaps best illustrate by the fact that it was possible to make an 83-gra per sq. meter sheet from the same stock with a Gurle porosity varying from 22 to 3000 sec.

When the fiber suspension passes the newly forme mat of fibers on the wire, some fibers will not be com pletely embedded in the sheet and will either be de flected parallel to the direction of liquid flow or ma be torn out of the structure and carried away by th stream. As mentioned earlier, the washing off effec will be more pronounced at higher velocities of th stock. When the sheet builds up and its drainage re sistance increases, it will become less probable that long fiber will be taken from the suspension and becom stuck to the sheet surface. This effect will result i a fiber fractionation, increasing with basis weight i accordance with the observations on sheet density an the increase in specific drainage resistance at hig velocities of flow past the wire.

In this connection it is interesting to note that th bulk of the sheet formed on the probe is dependent o the consistency of the stock.

When comparing the bulk of the sheets formed fro stock of different consistencies under otherwise simila

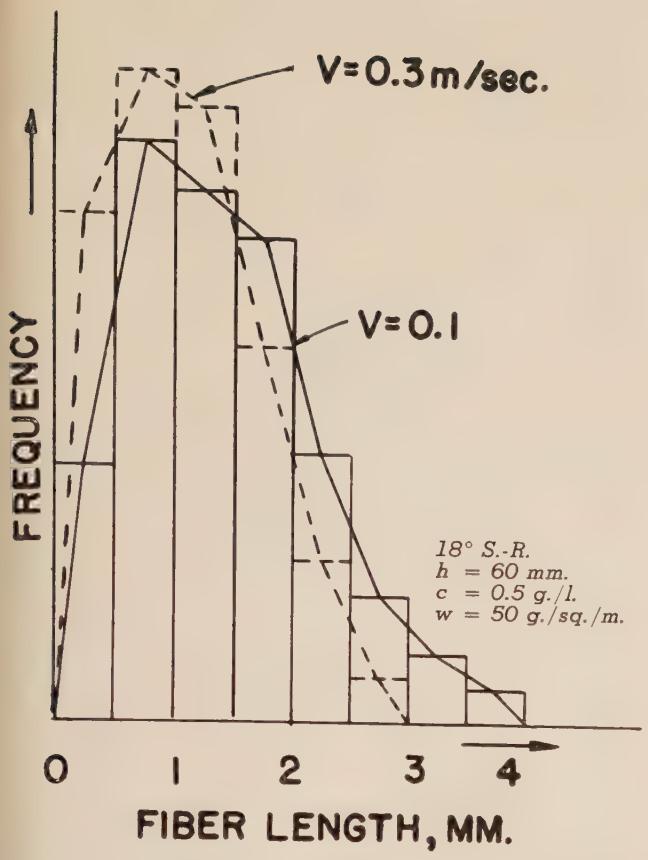

Fig. 10. Fiber length distribution in probe sheet (50 grams per square meter) at 0.1 and 0.3 meters per sec. stock flow past the wire

conditions two different regions were found—namely, one for low basis weights (under 30 to 40 grams per sq. meter) and one above this limit, as shown in Fig. 13.

In the lower range a dilute stock gives a bulkier sheet. In the higher range the opposite is true. It could be presumed that a deflocculated low consistency stock would always allow formation of a denser sheet than a stock of higher consistency and consequently of higher degree of flocculation. However, at extremely low consistencies the rate of drainage is so high, even at moderate making heads, that the fibers will not have sufficient time to find the ideal positions in the sheet and consequently a low density sheet is obtained. Only when a sheet of sufficient substance is formed has the rate of drainage decreased to the extent that further substance increase can utilize the ideal conditions in the diluted stock. Under these conditions the above-mentioned fractionation effect will be pronounced and the sheet will become more compact. At higher basis weight a lower stock consistency always produced a denser sheet.

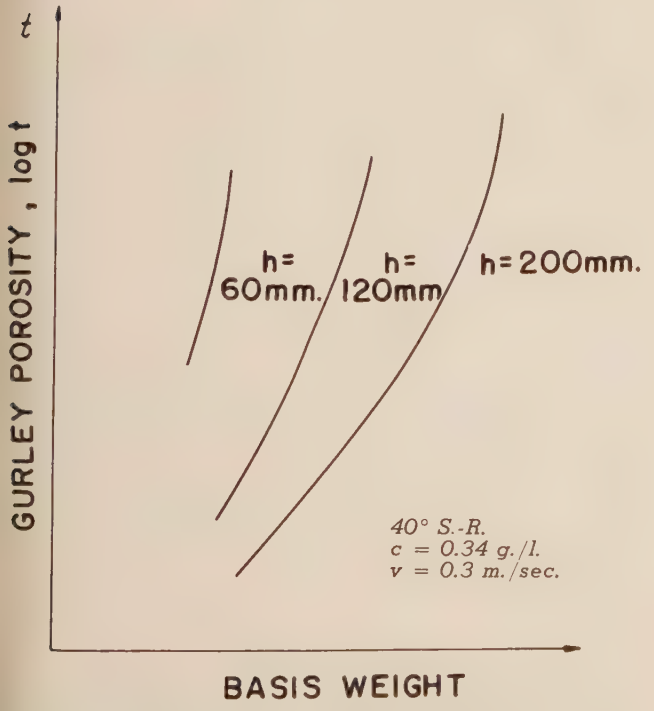

Fig. 11. Gurley porosity (t) of sheets formed on probe at different making heads (h)

Of the mechanical properties studied, only tensile strength will be discussed. This was measured on the STFI universal stress strain instrument of Ivarsson and Steenberg (*10*). Strength determinations were made in the direction of the flow over the probe (designated as machine direction) and at right angles to this direction (cross direction). The results are shown in Figs. 14 and 15 for different velocities of flow past the wire and for different consistencies.

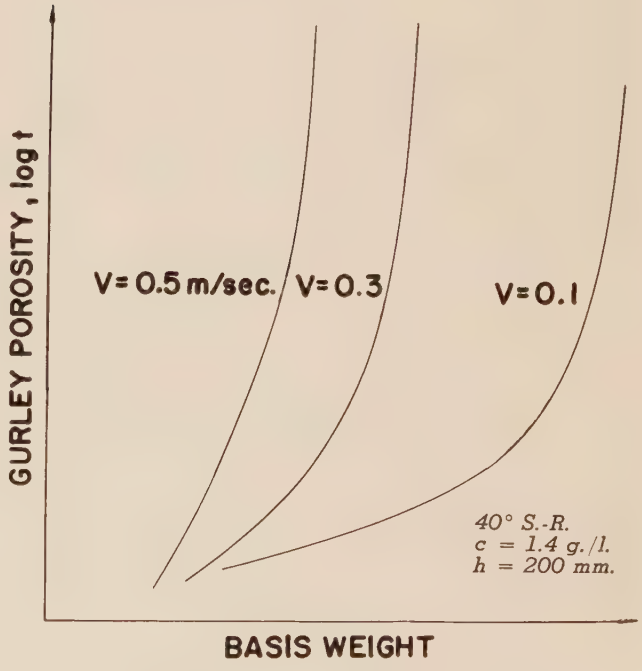

Fig. 12. Gurley porosity (t) of sheets formed at different rates of flow past the wire (v)

The experiments carried out at 0.3 meter per sec. flow of stock relative to the wire showed that tensile strength in both directions generally increased with increasing consistency in the region studied. At these high rates of flow relative to the probe, the stock is essentially deflocculated. The "machine-direction" effect is easily observed, but it should be remembered that in no case was the ratio between tensile strength in machine and cross direction significantly above 2.5. In the experiments at less than 0.2 meter per sec. flow past the wire the difference in strength in the machine and the cross direction is smaller. This is the case for lower making heads. At higher consistencies and low

velocities of stock past the wire, the stock is more flocculated and good formation is prevented. The result of a high degree of flocculation is most pronounced in the tensile strength of the machine direction.

Fiber orientation was studied in experiments with about 1% dyed fibers in the stock, according to Danielsen and Steenberg (*11*). It was found that the degree of fiber orientation increased with increased rate of flow past the wire. The wire side of the sheet had a lower degree of orientation than the top side. In one experiment (40° S.-R., consistency = 1.4 grams per

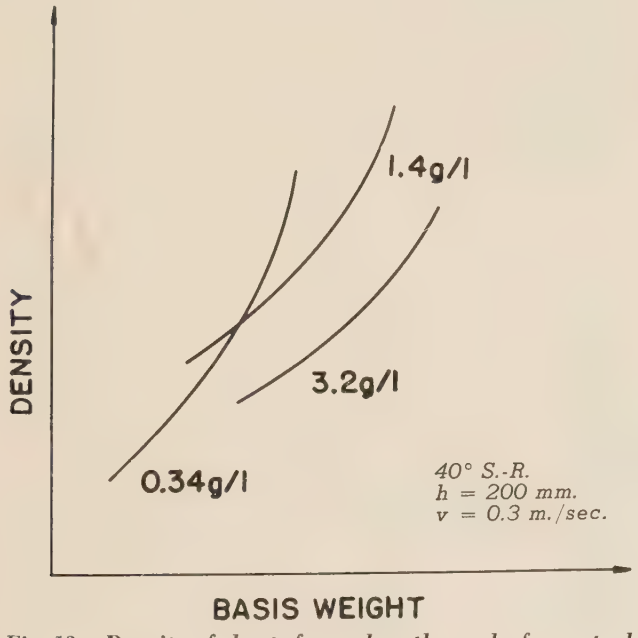

Fig. 13. Density of sheets formed on the probe from stock of varying consistencies

liter, h = 200 mm.) the percentage of fibers within an angle of ±30° from the machine direction were as shown in the following table.

Stock velocity, meter per sec.	*Degree of fiber orientation, %*	
	Wire side	*Top side*
0.1	66	59
0.3	67	77
0.5	75	83

DISCUSSION OF SHEET FORMATION IN CYLINDER MOLDS

In a cylinder machine vat, the consistency at a point further from the inlet is always higher than at a point nearer the inlet, irrespective of the type of mold. This is understandable from the fact that at a later stage of the sheetforming process some drainage always occurs without a corresponding deposition of fibers, as clearly demonstrated in the model experiments.

Because of the earlier mentioned fiber fractionation which takes place as the sheet is being formed on the cylinder wire, the freeness of the stock will vary along the vat circle. The freeness will increase with increasing distance from the inlet. This has been confirmed by tests in both direct-flow vats and counterflow vats. In a counterflow vat a difference of 20° S.-R. has been recorded between the stock at the inlet and the stock which the clean wire meets at the other end of the vat

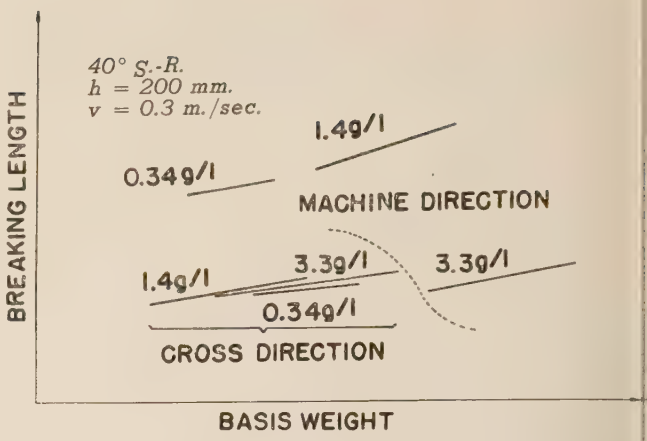

Fig. 14. Breaking length of sheets formed on the probe from stock of different consistencies; high rate of flow past the wire (0.3 meter per sec.)

circle. In a direct-flow vat the difference is smaller the larger the overflow of the vat is, but it can always be detected.

As a consequence of the above-mentioned conditions the sheet on a cylinder wire is made from a stock of varying consistency and freeness. In a counterflow machine the naked wire will meet the freest and most concentrated stock. In this region, however, the growth of the sheet is rapid and proceeds approximately ideally, i.e., the quantity of fiber deposited on the wire is proportional to the drained volume of water. Although nonideal conditions prevail through the rest of the vat a steady state is eventually obtained for the vat as a whole, and no overflow is necessary.

In a direct-flow machine the clean wire meets the most dilute stock. Initially, the sheet substance increases in direct proportion to the quantity of drained water. As the consistency is low the rate of drainage high, causing a less well-formed sheet and a high throughfraction of short fibers and fines. Later on in the sheetforming process less fibers are attached to the sheet in proportion to the drained volume of water, and the concentration and freeness of the stock will increase along the vat circle. Obviously no steady state is reached in this case, and an overflow is necessary to prevent excessive consistency in the vat.

Explanations given in the literature for the necessity of an overflow in direct flow vats and a comparison wit

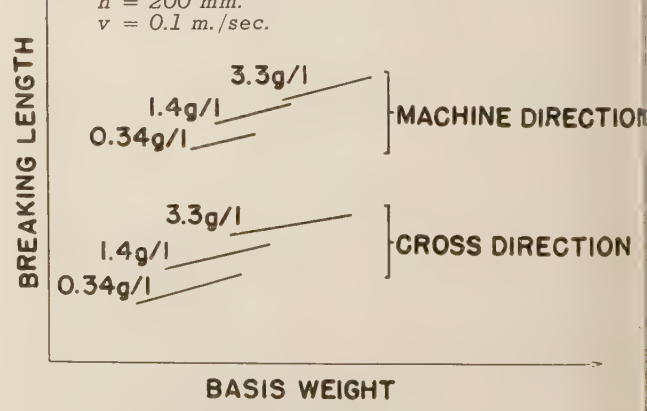

Fig. 15. Breaking length of sheets formed on the probe from stock of different consistencies; medium rate of flow past the wire (0.1 meter per sec.)

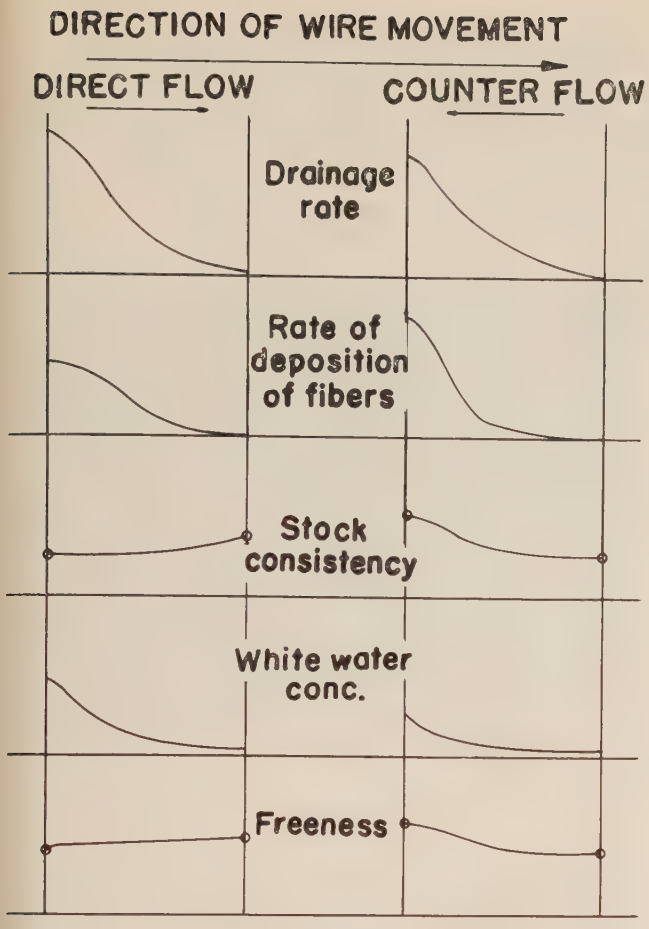

Fig. 16. Comparison of sheetmaking conditions in direct and counter flow vats

counterflow vats in this respect are generally vague and incomplete.

In the model experiments the sheet was formed from a stock of constant consistency and freeness having a uniform velocity relative to the wire. Obviously none of these conditions exists in the cylinder machine. If (for the present) the varying velocity of the stock in different parts of the vat is neglected, it is, however, possible to draw some conclusions regarding the much discussed question of the rate of growth of the sheet on a cylinder wire.

In the counterflow vat the rate of substance growth increases rapidly during the generally short period of increasing making head, and then decreases proportionally to the decreasing rate of drainage. This part of the sheet is formed from a high consistency stock of high freeness and is relatively porous. It will have a proportionally greater drainage rate than a sheet of the same basis weight formed in the direct-flow process. The rate of flow past the wire can in this initial part of the sheet formation be considered to be relatively unimportant for the sheet characteristics, because formation is proceeding in the ideal way. Soon, however, the drainage resistance has reached higher values and the flow past the wire has a higher velocity and the stock has lower consistency and lower freeness. The rate of sheet growth in this period is much lower. The sheet is, however, closed as a result of picking up fiber fragments and shorter fibers.

It is generally held that a counterflow machine can satisfactorily pick up higher substance than a direct-flow machine. The relatively large part of the sheet made from a high consistency free stock is probably the reason for this effect. The high bulk of the sheet will make it ideal for the center of a board.

In the direct-flow vat the rate of drainage is very high in the beginning of the sheetforming process and will continue to be so over a larger distance than in the counterflow vat, because the consistency is smaller in the first case, and the total drainage resistance will build up more slowly. The sheet will, however, have a more closed formation as the process proceeds. It seems understandable that the maximum pickup in the direct flow is smaller than in the counterflow wire, as is generally considered to be the case. A better uniformity is obtained mainly because the first fiber layers are formed from a dilute and better deflocculated stock than in a counterflow wire.

While the above-mentioned general type of formation always exists it can be further concluded from the experiments that the rate of substance growth will be influenced by a number of factors and even in the same machine will depend very much on the consistency and type of stock, speed of machine and the total substance being formed on the wire. Two of the three different possibilities for sheet growth put forward by Hollis (*8*) can, however, be definitely ruled out.

The general conditions for sheet growth in a direct-flow vat and counterflow vat are given in Fig. 16. In the diagram the circles depict points which can be measured without much difficulty on commercial machines while running. In several cases either the integral of the curve or an average value can be determined.

Regarding the strong anistropy of cylinder machine sheets compared to those found in the present model experiments it must be remembered that there is a considerable draw of the commercial sheet as it is being fixed to the long wet felt, and that in all probability even a perfectly randomly formed sheet because of this draw will become more anisotropic in mechanical properties than in the fourdrinier case.

It is tempting to discuss practical conclusions regarding design of cylinder machines using the information obtained in this work. It is the opinion of the writers that the importance of a possibility to vary the making head during the sheet formation process has been neglected in comparison to the probably less important influence of varying the relative speed of wire and stock by adjustable vat circles.

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Stroboscopic Observations at the Wet End

COVER C. PORTER

Both cyclic and non-cyclic motions of sheet formation at the wet end may be observed by an industrial-type stroboscope. Machine adjustments and experimental work can therefore be carried out with a greater degree of accuracy.

In investigations of the portion of the fourdrinier machine generally comprising the forming section between the breast roll and the flat boxes, it is usually quite difficult to observe just what is taking place. It is generally difficult to observe all of the eccentricities of the moving sheet, and it is quite common even for trained observers to disagree as to what they saw or what they thought they saw. A very useful instrument in overcoming some of these difficulties is the stroboscope which is an instrument for studying or observing periodical or varying motion by means of periodically interrupted light.

Consider a flywheel on the end of a shaft rotating at 1800 r.p.m. Near the rim is painted a black spot. Let us view this flywheel in a darkened room by means of light which is flashed periodically 1800 times per min. Under this condition the flywheel will appear to be stationary because it is always in the same position when we see it. This is possible because of a rather remarkable property of the human eye known as persistence of vision. The retina of the eye will retain each image of the spot on the flywheel for an appreciable fraction of a second while the light source is off and therefore, no flicker of the dot on the flywheel rim is observed.

In referring to the various illustrations, more importance is to be placed on the stroboscope as an instrument of technical investigation rather than the subject matter of the illustrations themselves.

Figure 1 is a microflash photograph of 1 thousandth of a sec. duration taken with a commercial photographer's strobolight. This is identical in appearance for any given instant as when viewed under continuous stroboscopic illumination. This machine is a 238-in. fourdrinier running newsprint from southern pine at 1500 f.p.m., which has a conventional open headbox with a flat apron plate and a Van de Carr slice and utilizing fin-type flow eveners. The slice can be barely seen in the upper right and right-hand portions of the illustration. Following the slice a rather wide forming board supports the wire, followed by the first table roll. Quite a number of things are self-evident including the streaks left by the flow eveners, the nip effect at the first table roll after which considerable turbulence takes place, and also the friction effect against the atmosphere which tends to bend the spray back toward the headbox. At this point the author would like to re-emphasize the former statement that this illustration is of no particular importance as far as some findings of fact in the basic fundamentals of the wet end is concerned. It was found, however, that stroboscopic observations of this general nature were a great aid in investigations which involved the placement and sequence of table rolls, forming boards, deflectors, etc. In addition to resolving differences of opinion between trained observers, it was also most important to be able to demonstrate to operating personnel large machine changes which occurred with slight adjustments and at certain times conversely, the lack of change in the sheet conditions when some variables were changed rather drastically.

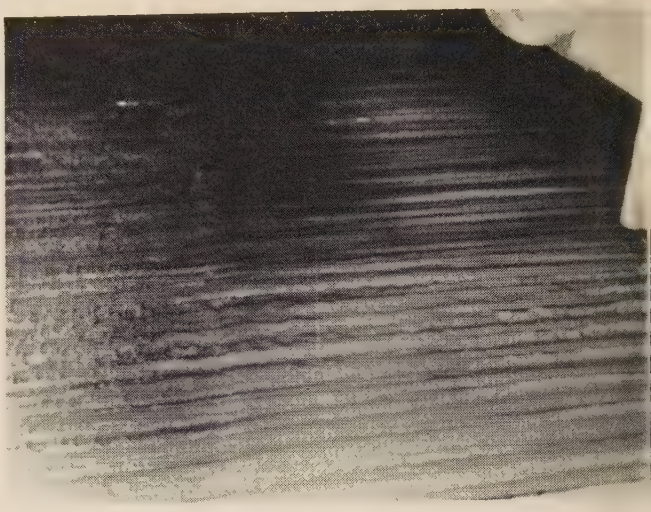

Fig. 1

Figure 2 is a view of the sheet on the wire about 6 ft. further down the wire than illustrated in Fig. 1. As can be seen, quite a bit of the turbulence has subsided. The end of the deckle can be seen in the lower right-hand corner, and the subsequent shock wave induced by the deckle about 12 in. toward the center of the wire. The top of the deflector between the two table rolls is also shown. This particular illustration was chosen to show

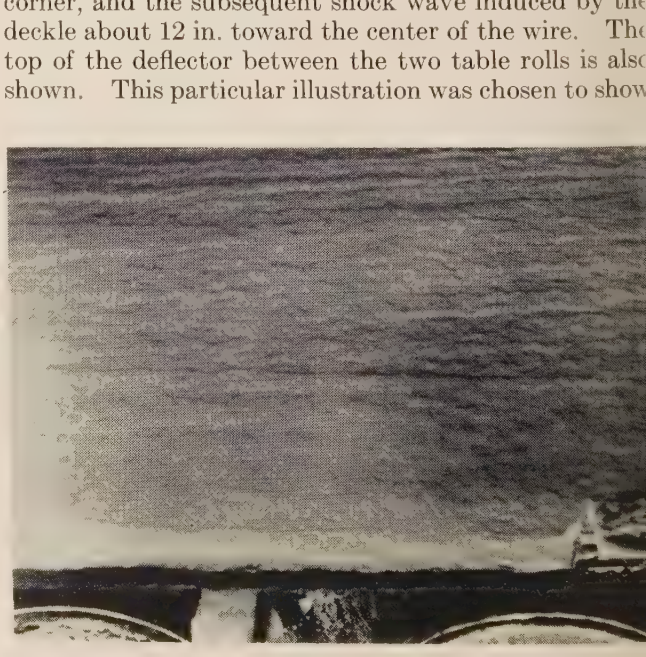

Fig. 2

Cover C. Porter, Assistant to General Manager, Southland Paper Mills, Inc., Lafkin, Tex.

Fig. 3

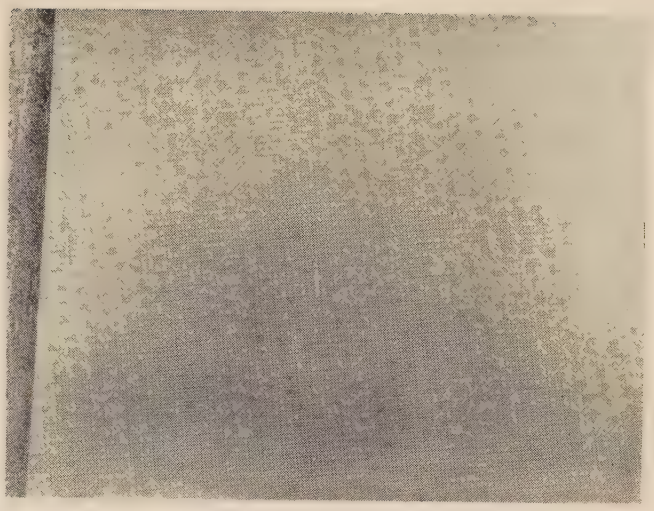

Fig. 4

that the wire was clearing the top of the deflector to the extent that deflector top itself is not removing any water. If it had been, a very definite nip would be seen under stroboscopic illumination that is very difficult to see with the naked eye.

Figure 3 shows the water leaving the breast roll. The forming board supporting the wire is seen at the top of the figure, the breast roll to the right, and the breast roll doctor in the foreground. It can be seen that the pattern of the water is, by and large, missing the doctor blade altogether. By use of stroboscopic illumination, it was possible to position the doctor blade so that the main stream is not driven into the point of contact but at the same time effectively cleans the roll.

Figure 4 is rather interesting in that it illustrates the distribution of the moisture content of the sheet entering the driers. To take this picture the photographer was laying on his back on the floor between the second press and the first drier. Continuous stroboscopic illumination indicates that the pattern originated from the couch. Unlike common cases of shell marking, the fibers are not physically dislocated as the sheet is clear at the dry end. Apparently the impression of the drilling is caused by the difference in the refractive or reflective index of the areas of different moisture content. In the drier section of 48 driers this pattern persists as far as no. 22 drier, but cannot be distinguished at no. 24. It is intended that continuing studies will be made of this phenomenon to see if the point of persistance advances or retreats up or down the drier section, which may give an insight to drying conditions in general. Here again is an example where visual demonstration completely changed the concept of moisture distribution that most of the operators previously had in mind.

Many other practical applications of stroboscopic application can be cited. It, of course, serves as a tachometer which requires zero power output from the object to be measured. In one case it was used to locate the source of trouble of a badly flapping draw in the drier section where the sheet transferred from the first drier felt to the second. It was obvious that a key had sheared in one of the two driers involved and under stroboscopic illumination the offender was seen to oscillate with each revolution. Considerable downtime was saved therefore in effecting the repairs.

The instruments in use in this mill are manufactured by General Radio Co. and are trade-named the Strobotac and the Strobolux. The Strobolux is used in conjunction with the Strobotac and supplies approximately 100 times as much light as the primary unit. The Strobolux can also be used as a microflash unit for high-speed photography. Although the illustrations were taken at 1 thousandth of a sec., the Strobolux supplies a microflash some 30 times faster. The combined cost of the two instruments in 1950 was $365 with replacement bulbs totaling about $30. This seems to be a small price for so valuable a research tool.

The Filtration Resistance of Pulp Slurries

W. L. INGMANSON and ROY P. WHITNEY

This paper is devoted to a presentation and discussion of the average specific filtration resistance as an important property of papermaking fibers. The laboratory determination of this quantity through both constant-pressure and constant-rate filtration experiments is discussed, and the relative merits of the two techniques are considered.

The analysis of filtration resistance into certain components, notably the specific surface and the effective specific volume, is also explored. Finally, the application of these concepts to drainage on the wire of the fourdrinier paper machine is proposed.

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The drainage of water from pulp slurries is an operation of first importance in papermaking. Since drainage is essentially an example of filtration, it is

surprising that relatively little attention has been paid to the application of existing filtration theories to drainage, or to the development of new theories particularly pertinent to papermaking fibers. The need for a better understanding of the mechanism of drainage is now generally recognized, and several important researches in this field are under way in laboratories both here and abroad.

Mathematical statements and developments of filtration theory have been presented by numerous authors (*1*, *2*, *3*). While a filtration may be conducted according to any desired schedule, most of the theoretical developments have been restricted to either a constant pressure differential across the filter mat, or a constant rate of filtration. Each of these restrictions has certain advantages, both in theory and in practice. The constant-pressure schedule is of particular interest in the pulp and paper field, because many of the practical applications either follow or approach this condition of restraint.

For the case of a constant-pressure filtration involving a noncompressible filter bed, the validity and utility of an "average specific filtration resistance" can easily be demonstrated. Such a concept is also valid for a compressible filter mat. Although in this case both the degree of compaction and the resistance to flow offered by a unit mass of solids vary markedly through the mat from face to septum, the *average* specific filtration resistance through the mat is not a function of mat thickness or mass, but only of the pressure differential across it.

For the constant-rate case, the pressure differential across the bed increases with time. Since, with a compressible bed, the average specific filtration resistance is a strong function of the pressure differential, it too must increase with time, and its significance is more difficult to interpret.

The filtration characteristics of pulp slurries have been under investigation in this laboratory for the past several years. The initial experimental approach involved the constant-pressure technique because of the simplicity and directness in interpretation of the results. For a given pulp slurry, it was necessary to conduct several experiments, each at a different pressure differential, in order to express the average specific filtration resistance as a function of the pressure differential. This early work has been described by one of the authors (*4*).

In spite of the difficulties in interpretation of the results, there are many experimental advantages offered by the constant-rate technique. Each experiment is simpler and less time-consuming, fewer calculations are involved, and it is possible to obtain the filtration resistance at any desired pressure differential from one experiment. The validity of the results so obtained, particularly if they are to be applied under constant-pressure conditions, has not been demonstrated, however. Nevertheless, use of the constant-rate technique has been proposed (*5*) and investigated extensively. This will be discussed below.

It is the belief of the authors that the average specific filtration resistance is an important property of a pulp slurry. It is a reliable index of drainage characteristics, which can be utilized in the design and operation of commercial equipment. However, it gives no indication, *per se*, of the mechanism of filtration or drainage, and permits no insight into the more fundamental properties which must govern it. Such an insight is possible, at least to some extent, by an analysis of the filtration resistance into its components. In this study, this has been accomplished by application of the Kozeny-Carman permeation relationship (*6*, *7*).

The Kozeny-Carman equation relates the rate of flow of an incompressible fluid through a fixed porous bed to the specific surface, the effective specific volume, and the compressibility characteristics of the bed. It is limited to the streamline region of flow, and to certain ranges of void fraction (*5*, *8*). Ingmanson (*4*) has shown that it may be applied in differential form to the filter mat of a compressible material such as pulp fibers, and then integrated over the proper boundary conditions. By this means, the filtration resistance can be expressed in terms of certain of its components.

It is the primary object of this paper to present the concept of the average specific filtration resistance as an important pulp property. The laboratory determination of this quantity by two means will be discussed, and the relation between the two examined critically.

Nomenclature

A	= cross-sectional area of bed perpendicular to direction of flow (49.5 sq. cm. for septum)
a	= table roll radius, centimeters
B	= constant in a constant-rate filtration, $B = A^2/\mu C(dV/d\theta)^2$, c.g.s. units
B'	= constant in a constant-pressure filtration, $B' = \mu C/A^2\Delta P_f$, c.g.s. units
b	= porosity integration constant, (centimeters per second)^2
C	= mass of fibers in filter bed per unit volume of filtrate, grams per cubic centimeter
c	= mass of fibers per unit volume of a uniformly compacted bed, grams per cubic centimeter
$c_{av.}$	= average mass of fibers per unit volume of a filter bed, grams per cubic centimeter
g	= acceleration due to gravity, 980 cm./sec.^{2}
J	= height of the column of water in a table roll nip, centimeters
k	= Kozeny constant, dimensionless
L	= width of fourdrinier wire, centimeters
M, N	= compressibility constants in relationship, $c = Mp^N$
M_0	= filter bed concentration at zero compacting pressure, grams per cubic centimeter
m	= ratio of mass of wet filter bed to mass of dry filter bed, dimensionless
ΔP_f	= over-all frictional pressure drop across filter bed, dynes per square centimeter
p	= mechanical compacting pressure in a filter bed, dynes per square centimeter
q	= volumetric rate of drainage from a table roll per unit width of wire, cubic centimeters per (second) (centimeter)
R	= average specific filtration resistance, centimeters per gram
S	= specific surface of fibers, external surface area per unit mass, square centimeters per gram
s	= mass of fibers per unit mass of slurry, dimensionless
u	= paper machine wire velocity, centimeters per second
V	= filtrate volume, cubic centimeters
v	= effective specific volume of fibers, cubic centimeters per gram
W	= total mass of fibers in a filter bed, grams
W'	= mass of fibers per unit area on paper machine wire, grams per square centimeter
$W'_{av.}$	= arithmetic average of W' entering and leaving drainage area at a table roll, grams per square centimeter
w	= mass of fibers above some given point in a filter bed, grams
x	= length of drainage area at a table roll, centimeters
ϵ	= filter bed porosity at a given point, void volume per bed volume, dimensionless
$\epsilon_{av.}$	= average porosity of a filter bed, dimensionless
θ	= time of filtration, seconds
μ	= filtrate viscosity, poises
ρ	= filtrate density, grams per cubic centimeter

Analysis of the filtration resistance into certain of its components will be considered. Finally, the utility of these concepts in the study of drainage on the wire of the fourdrinier paper machine will be indicated briefly.

LABORATORY MEASUREMENT OF FILTRATION RESISTANCE

Filtration theory has been previously discussed by the authors (*4*, *5*), and the defining equation for the average specific filtration resistance of a compressible material, such as cellulosic fibers, was written in the conventional manner as,

$$\frac{dV}{d\theta} = \frac{A\Delta P_f}{\mu(W/A)R} \qquad (1)$$

where $dV/d\theta$ is the volumetric rate of flow past a cross-sectional area, A, of a filter bed containing a mass of particles, W. The over-all frictional pressure drop across the filter bed is ΔP_f in a fluid with viscosity μ, and R is the average specific filtration resistance of the bed. The mass of particles in the bed may be related to the filtrate volume by a material balance:

$$W = \frac{\rho s}{1 - sm} V = CV \qquad (2)$$

where ρ is the filtrate density, s is the mass fraction of solids in the slurry, i.e., the slurry consistency, m is a measure of the moisture content of the filter bed expressed as the mass ratio of wet filter bed to dry filter bed, and C is the mass of particles in the filter bed per unit volume of filtrate.

Constant-Pressure Filtrations

In a previous study (*4*), constant-pressure filtration data were analyzed by integrating equation (1) over the limits of filtration time, θ, and filtrate volume, V, during which the pressure drop across the bed was constant. The resulting equation was rectified and plotted in such a manner that the filtration resistance at a given pressure drop could be calculated from the slope of the linear curve. This method is not particularly sensitive to detecting possible changes of filtration resistance with time of filtration, and extrapolation of the filtration curve to conditions of zero pad weight is complicated by the initial variation in pressure drop and filtration resistance. A more sensitive method of analysis can be obtained by writing a combination of equations (1) and (2) in an incremental form, and rearranging the terms to give,

$$\frac{\Delta\theta}{\Delta V} = \frac{\mu CR}{A^2\Delta P_f} V = B'RV \qquad (3)$$

where B' is constant for a given filtration.

When the incremental time, $\Delta\theta$, and the corresponding incremental volume, ΔV, are taken sufficiently small, a plot of the left side of equation (3) against the average volume, V, is linear for a constant average specific resistance, R, and the slope of the curve may be used to calculate the filtration resistance. A plot of equation (3) should extrapolate to zero volume at zero $\Delta\theta/\Delta V$, if R is independent of the filtration time, θ.

Constant-Rate Filtrations

In a constant-rate filtration, the volumetric flow rate is maintained constant, and the frictional pressure drop across the bed increases as the mass of particles in the bed builds up. Since the moisture content of the filter bed, m, is a function of the pressure drop, equation (2) is rewritten as,

$$W = \frac{dV}{d\theta}\int_0^\theta \frac{\rho s}{1 - sm}\, d\theta = \frac{dV}{d\theta}\int_0^\theta C d\theta \qquad (4)$$

From equations (1) and (4), the filtration resistance, at some given pressure drop, may be expressed as,

$$R = \frac{A^2\Delta P_f}{\mu(dV/d\theta)^2 \int_0^\theta C d\theta} \qquad (5)$$

For a relatively dilute slurry (i.e., less than 0.1% consistency), C is very nearly equivalent to the slurry consistency, s, and may be assumed to be independent of the pressure drop. Under these special conditions equation (5) simplifies to,

$$R = \frac{A^2}{\mu C(dV/d\theta)^2}\frac{\Delta P_f}{\theta} = B\frac{\Delta P_f}{\theta} \qquad (6)$$

where B is constant for a given filtration. Knowledge of the filtration constant, B, and the time-pressure drop relationship in a constant-rate filtration can be used to calculate the filtration resistance as a function of the pressure drop directly from equation (6). For slurry consistencies greater than 0.1%, the factor $(1-sm)$ in equation (2) differs appreciably from unity, and the slurry consistency s may no longer be taken equivalent to C. In this case, the mass ratio of wet pulp bed to dry pulp bed, m, must be known as a function of the frictional pressure drop, and the integral in equation (5) is evaluated graphically at the pressure drop for which the filtration resistance is to be calculated.

Components of Filtration Resistance

The well-known Kozeny-Carman equation can be used to relate the filtration resistance of porous beds to certain properties of the materials comprising the bed. It has been shown (*4*) that the average specific filtration resistance at pressure drop ΔP_f is given by,

$$R = \frac{kS^2\,\Delta P_f}{\int_0^{\Delta P_f} [(1 - vc)^3/c]\, dp} \qquad (7)$$

where k is the Kozeny constant, taken as 5.55 for fibrous materials (*9*), S is the specific surface, v is the effective specific volume, p is the mechanical compacting pressure developed at a point in the bed, and c is the point concentration of bed material at a differential layer in the filter mat where the compacting pressure is p.

Equation (7) can be used to calculate the specific surface and the specific volume of pulp fibers, provided the functional relation between the pad concentration, c, and the compacting pressure, p, is known. In the pressure range from 10 to 100 cm. of water, experimental compressibility data for many wood pulps can be fitted with good precision by an empirical function of the form

$$c = Mp^N \qquad (8)$$

where M and N are constants. When equation (8) is substituted in equation (7), integration yields:

$$R = \frac{kS^2}{[c^{-1}/(1 - N)] - 3v + [3v^2c/(1 + N)] - [v^3c^2/(1 + 2N)]} \qquad (9)$$

Provided the compressibility constants and the filtra-

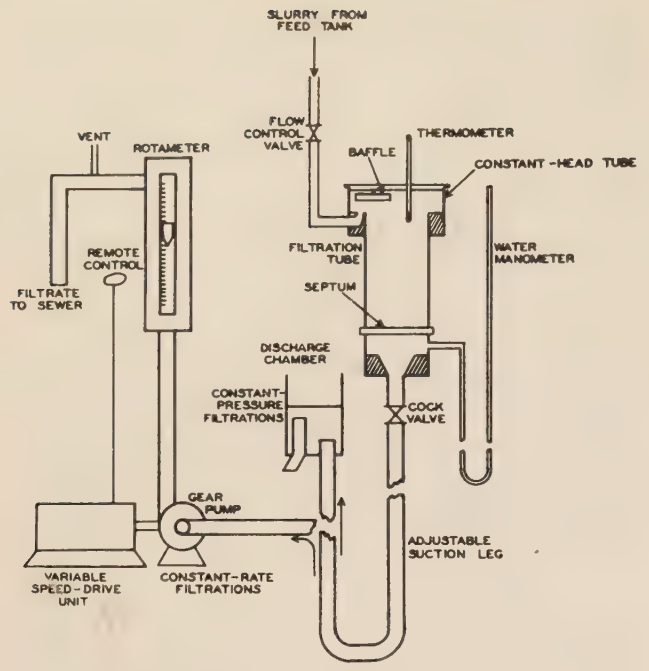

Fig. 1. Combination constant-pressure and constant-rate filtration apparatus

tion resistance at two or more values of the pressure drop are known, equation (9) can be used as a working relation for the determination of the specific surface and the specific volume. However, it is subject to the serious limitations of the empirical function expressed in equation (8).

The assumption inherent in equation (8) is that the pad concentration is zero at zero compacting pressure (i.e., at the pad face). Although this has been shown to be a good approximation in some cases, (*10*), it cannot be strictly true. There is a finite value of the pad concentration at the pad face, which may be called M_0, and it is evident therefore that a better empirical compressibility function would take the form $c = M_0 + Mp^N$. However, an accurate determination of M_0 has not yet been accomplished, and substitution of this compressibility function into equation (7) gives a relation which cannot be integrated by formula. For these reasons, in the analysis of the constant-pressure filtrations, it has been necessary to take M_0 equal to zero, and to use equation (9) as the working relation.

Equation (9), an integrated form of the Kozeny-Carman relation, can also be used in the analysis of constant-rate filtration data, still subject, of course, to the uncertainties discussed above. It is possible, however, to calculate the specific surface and specific volume from constant-rate filtration data in a manner which does not necessitate extrapolation of the compressibility data, and is independent of any assumptions concerning the value of the pad concentration at zero compacting pressure. When the value for filtration resistance given by equation (7) is substituted into the constant-rate relationship of equation (6), the resulting expression for filtration time may be differentiated with respect to pressure drop. This differentiation serves to remove the integral sign in equation (7) and the equation may be rectified to yield (*5*):

$$\left[c\,\frac{d\theta}{d(\Delta P_f)}\right]^{1/3} = \left[\frac{B}{kS^2}\right]^{1/3}[1 - vc] \qquad (10)$$

Values of $d\theta/d(\Delta P_f)$ may be determined from the time-pressure drop curve of a constant-rate filtration, and compressibility measurements can be used to obtain values of the pad concentration, c, at compacting pressures equal to the pressure drops at which the slopes were measured. Then, a plot of the left side of equation (10) against the pad concentration, c, should be linear if the Kozeny-Carman relationship holds over the porosity range in question. The value of the $c = 0$ intercept and the slope are used to evaluate the specific surface, S, and the effective specific volume, v. An example of this type of analysis of constant-rate filtration data has been given for a spruce sulphite pulp (*5*).

Experimental Methods

The filtration apparatus, slurry feed system, and pulp preparation described in previous constant-pressure work (*4*) was utilized in the constant-rate experiments by connecting a variable-speed gear pump to the suction leg of the filtration tube. A schematic sketch of the combination constant-rate and constant-pressure filtration apparatus is shown in Fig. 1.

Pulp slurries from the gravity feed tank were admitted through the side of the constant-head section of the filtration tube with a baffle system to prevent surging of the slurry level in the tube. The turbulence of slurry flow into the tube was sufficient to prevent settling out of the fibers during filtrations, and no other means of agitation was necessary. Standard slurry consistencies of 0.01% (to avoid all flocculation effects) were used in all the filtrations except those in which slurry consistency was the variable under study.

Compressibility measurements were made on pulp pads formed in the filtrations. The pads were allowed to expand at the end of the filtration and a permeable brass piston loaded with weights was used to compress the beds over a compacting pressure range of 10 to 100 cm. of water. Pad thicknesses were measured with a cathetometer.

The pulps used in the investigations were dewatered to oven-dry contents of from 25 to 30%. The pulps were soaked overnight before the filtrations, dispersed in a standard British disintegrator, and deaerated under water pump suction before being added to the feed tank and diluted.

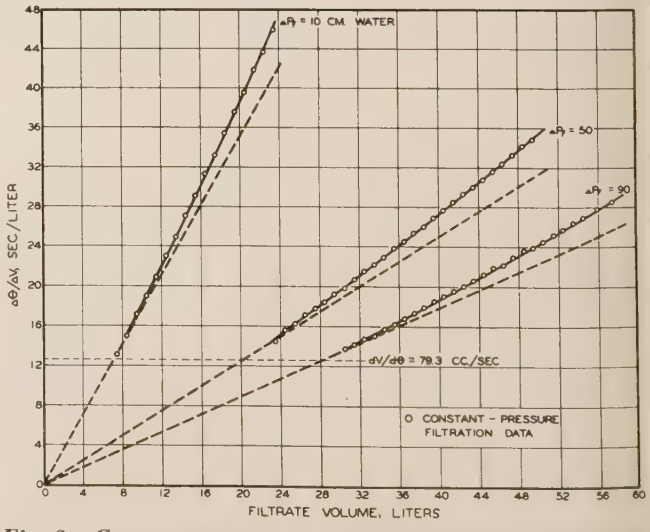

Fig. 2. Constant-pressure filtrations—red oak kraft pulp

COMPARISON OF CONSTANT-RATE AND CONSTANT-PRESSURE FILTRATIONS

In the evaluation of the constant-rate technique as a laboratory tool in the measurement of filtration resistance, both constant-rate and constant-pressure filtrations were made on a number of different pulps. To make the comparisons under the most nearly similar experimental conditions, the initial periods of the constant-pressure filtrations, which were required to build up the pressure to the desired constant values, were made as nearly as possible at the constant flow rate used in the separate constant-rate studies.

A typical example of the constant-pressure filtrations is shown in Fig. 2 for a northern red oak kraft pulp. A line of constant rate, corresponding to the flow rate in the attendant constant-rate filtration, is drawn in Fig. 2. Had the initial flow rates in the constant-pressure experiments been exactly the same as indicated on the horizontal dotted line, the first datum points would have fallen exactly on this constant-rate line. These initial datum points have been extrapolated to zero V and zero $\Delta\theta/\Delta V$. The filtration resistances calculated from the slopes of the resulting lines agree with the constant-rate runs within 1%. Hence, the dotted extrapolation lines in Fig. 2 may be considered to represent hypothetical constant-pressure filtrations with filtration resistances equal to those calculated from the constant-rate runs. However, it can be seen that as the constant-pressure filtrations proceed, the $\Delta\theta/\Delta V$ values deviate more and more from the extrapolated curves. The filtration resistances measured in these constant-pressure periods of the runs are larger than those from the constant-rate runs by from 4 to 16%. These differences are graphically illustrated in Fig. 3, where it can be seen that the discrepancies in filtration resistance become greater at higher pressure drops.

Using the experimentally determined pad compressibility data, it is possible now to calculate values of the pulp specific surface and effective specific volume from both the constant-pressure and the constant-rate filtration resistances, using the integrated Kozeny-Carman equation (equation 9). In addition, the specific surface and specific volume can be calculated directly from the constant-rate data, using the differential form of the Kozeny-Carman equation (equation 10). The three sets of calculated values are shown in Table I, where it can be seen that all three values of the

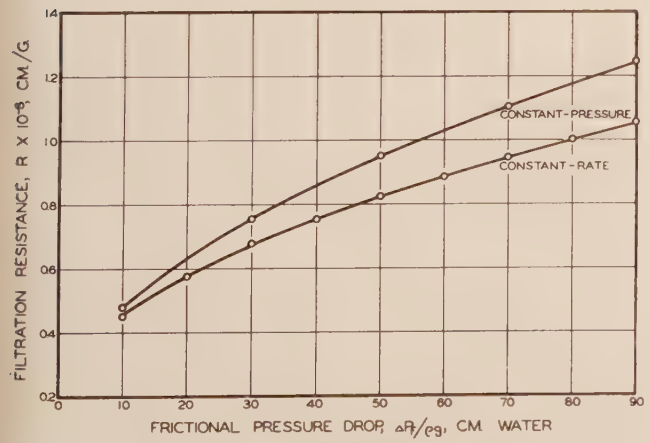

Fig. 3. Comparison of constant-pressure and constant-rate filtrations—red oak kraft pulp

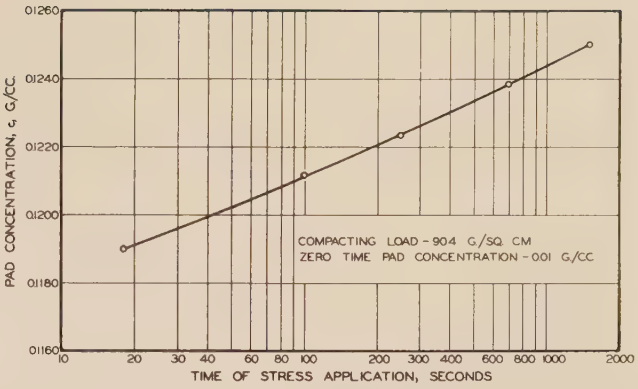
PAD CONCENTRATION, c, G/CC
TIME OF STRESS APPLICATION, SECONDS
COMPACTING LOAD - 90.4 G/SQ. CM.
ZERO TIME PAD CONCENTRATION - 001 G/CC

Fig. 4. Deformation of wet pulp pad under constant stress —red oak kraft pulp

specific surface are in good agreement, but that the specific volumes differ markedly. Not only is the constant-pressure specific volume significantly higher, but the two values calculated from the constant-rate data are not in agreement between themselves. The latter discrepancy must reflect the difference in the two forms of the Kozeny-Carman equation.

Since the only real difference between the two forms of the Kozeny-Carman equation is the dependency of the integrated form upon the accuracy of the extrapolation of the compressibility function to zero pad concentration, an extrapolation error is indicated. As would be anticipated, when the specific surface and specific volume calculated from the differential form are substituted into the integrated expression, filtration resistance values are calculated to be significantly lower than those measured in constant-rate experiments. The desired integral, Y, is,

$$Y = \int_0^{\Delta P_f} \frac{(1 - vc)^3}{c}\, dp \qquad (11)$$

However, when the expression based on extrapolation of the compressibility function, $c = Mp^N$, and given by equation (9) is used, the integrated porosity function is too large by some area, b. Area b is defined by the assumed compressibility function and by some actual but unknown function, say $c = M_0 + Mp^N$. Thus, the proper integration is given by,

$$Y = \int_0^{\Delta P_f} \frac{(1 - vMp^N)^3}{Mp^N}\, dp - b \qquad (12)$$

Provided the upper limit, ΔP_f, of the porosity function integral is greater than that at the point of divergency of the assumed and actual compressibility functions, area b should be constant and independent of the pressure drop.

Values of the specific surface and specific volume

Table I. Specific Surface and Specific Volume—Red Oak Kraft

	Specific surface, S, *sq. cm./g.*	*Specific volume*, v, *cc./g.*
Constant-pressure, integrated Kozeny equation[a]	10,600	2.78
Constant-rate, integrated Kozeny equation[a]	10,950	2.02
Constant-rate, differential Kozeny equation[b]	10,470	2.245

[a] Equation (9).
[b] Equation (10).

given by the differential form of the Kozeny-Carman equation were used in conjunction with the compressibility constants and constant-rate data to calculate b at five pressure drops by using equations (7) and (12). The values of the correction area b are given in Table II for the red oak pulp, and appear to be reasonably

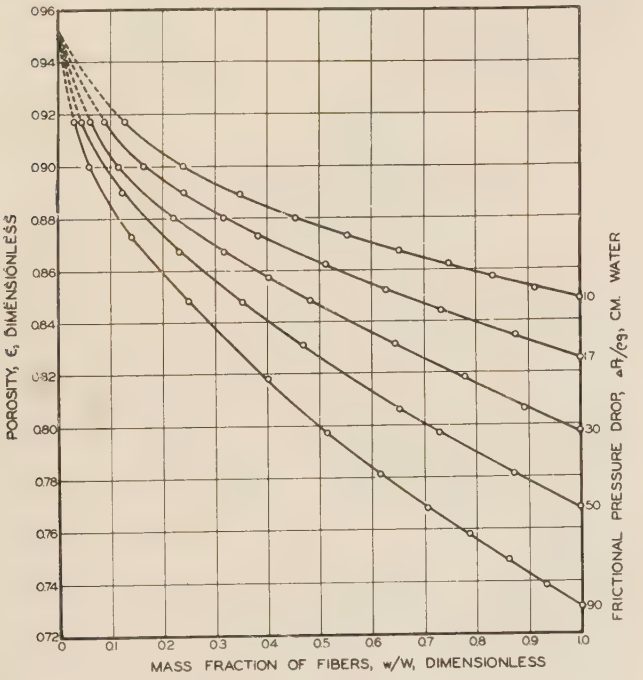

Fig. 5. Porosity distributions in filter beds of red oak kraft pulp

constant and independent of pressure drop. When the average b values are substituted into equation (7), the values of filtration resistance calculated from the *corrected* integrated Kozeny-Carman equation agree perfectly with the constant-rate data of the red oak pulp (Table II). These results are typical of those found for a number of other wood pulps.

It is concluded that use of the integrated Kozeny-Carman equation to calculate specific surface or specific volume from either constant-rate or constant-pressure filtrations is not in perfect agreement with the experimental data because of the necessity of extrapolating an empirical compressibility function. More reliable values of the specific surface and specific volume may be obtained from the time-pressure drop curves of constant-rate filtrations, and from compressibility data used only in the pressure range over which the data were experimentally measured. Values of the specific surface, calculated by either method and from either constant-rate or constant-pressure filtrations, are reasonably similar and can be considered in good agreement. Deficiencies in the theories and errors in the measurements appear to be largely absorbed in the apparent values of the effective specific volume.

Table II. Porosity Function Integration Constant, Red Oak Kraft

Pressure drop, $\Delta P_f/\rho g$., *cm. water*	*Integration constant,* $b \times 10^{-3}$, *cm.²/sec.²*	*Filtration resistance,* $R \times 10^{-8}$, *cm./g.* — *Calculated from constant rate filtration data*	*Calculated from integrated Kozeny-Carman equation* ($b = 0$)	*Calculated from integrated Kozeny-Carman equation* ($b = 10.6$)
10	9.2	0.459	0.429	0.462
30	10.1	0.673	0.648	0.673
50	10.8	0.820	0.795	0.820
70	9.5	0.940	0.916	0.940
90	12.6	1.049	1.020	1.043
Av.	10.6			

The reason for larger values of the filtration resistance *per se* from constant-pressure filtrations in comparison with constant-rate filtrations is yet to be explained. The graphical analysis of the constant-pressure data in Fig. 2 indicates the possibility of a time effect on filtration resistance. The filtration times for the red oak kraft pulp were purposely made as long as possible, and a definite curvature was observed in the constant-pressure graph. Similar curvatures, indicating an increase in filtration resistance with the time of filtration, have been found for both unbeaten and beaten pulps. Because of the viscoelastic nature of wet pulp pads, creep effects have been observed by a number of workers (*11–13*) for wet pulps under compressive stress. Thus, it is possible that examination of porosity distributions, porosity changes, and rate of loading within filter beds under conditions of constant-rate and constant-pressure filtrations might afford some insight into the observed differences in the two types of filtrations.

Creep effects have been noted for a large number of pulps in compressibility studies. An example of the type of deformation that is obtained under sustained load is shown in Fig. 4 for the red oak pulp. In this one experiment, the load was applied as quickly as possible to the pad face by a permeable piston. In the relatively short time of 18 sec., the mat was compressed from a concentration of 0.0100 to 0.1190 gram per cc. From this point, the pulp bed concentration was roughly proportional to the logarithm of time.

In conducting the actual compressibility tests, loads of from 10 to 100 grams per sq. cm. were applied in succession to the expanded pads resulting from the filtrations. It was necessary to apply each load slowly to prevent a shifting of the relative positions of fibers within the pads. Loads were applied in such a manner

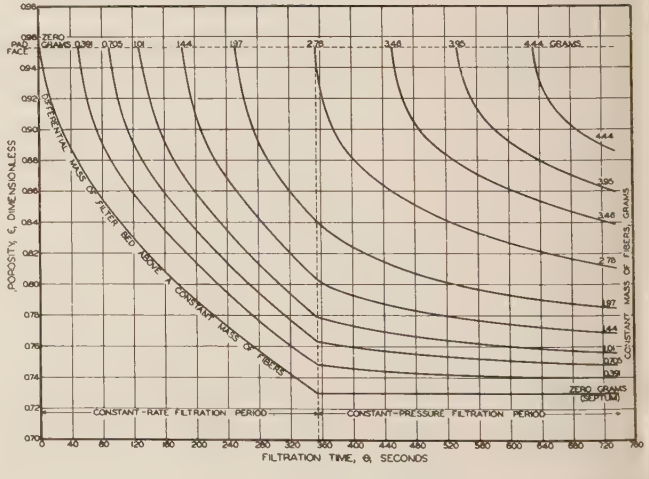

Fig. 6. Porosity change in filter beds of red oak kraft pulp

that liquid pressures not greater than 2 cm. of water were developed as the bed of fibers was compressed. Because of the creep effect, some arbitrary decision was necessary in order to choose an apparent pad concentration equilibrium point. In these studies, pad concentrations were measured when the liquid pressure differential, as indicated by the water manometer

(Fig. 1), was zero. This apparent equilibrium, when the flow of water from the compressed bed was too slow to indicate a pressure differential, occurred within 30 to 60 sec. after the full piston load was applied to the pad of fibers.

To calculate the pad concentration at various points in a filter bed, the distribution of compacting pressures throughout the bed must be known. It can be shown that the compacting pressure, p, at some point in the filter bed is related to the mass fraction of material, w/W, above that point by,

$$\frac{w}{W} = \frac{\int_0^p [(1 - vc)^3/c]\, dp}{\int_0^{\Delta P_f} [(1 - vc)^3/c]\, dp} \qquad (13)$$

The porosity, ϵ, of a differential mass of fibers at some point in the filter bed is given by,

$$\epsilon = 1 - vc \qquad (14)$$

where c is the concentration of the differential mass of fibers subjected to mechanical stress p.

Calculations of porosity distributions were made for the red oak kraft pulp with a specific volume, calculated from the differential form of the Kozeny-Carman equation, of 2.245 cc. per gram. Values of the integrated porosity function for this pulp were calculated from equation (12) using the average value of the integration constant, b, given in Table II. Then, for a given value of the compacting pressure at some point in the bed, the mass fraction of material above this point was calculated from equation (13). The porosity at this same point was calculated from equation (14) and the porosity distribution curves of Fig. 5 were constructed.

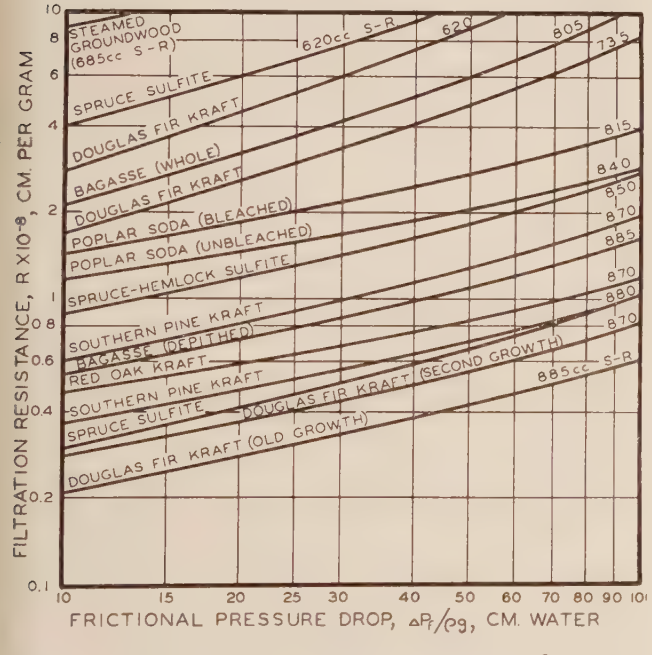

Fig. 7. Average specific filtration resistance—low range

For any constant-pressure filtration, the porosity distribution is given by one of this family of curves over the entire constant-pressure period. A differential mass of fibers within the pad may be selected at any value of the mass fraction, w/W, above it, and the change in porosity of this mass traced throughout the course of the constant-pressure filtration. This is done by keeping $W - w$ constant along a given frictional pressure drop line as W increases throughout the filtration. This is equivalent to moving from left to right on a constant-pressure line, and gradually approaching a value of w/W equal to unity. A similar procedure can be used for a differential element of mass in a constant-rate filtration. In this case, however, as w/W moves from left to right, new frictional pressure drop curves are continually encountered, so the constant mass also moves downward on the graph.

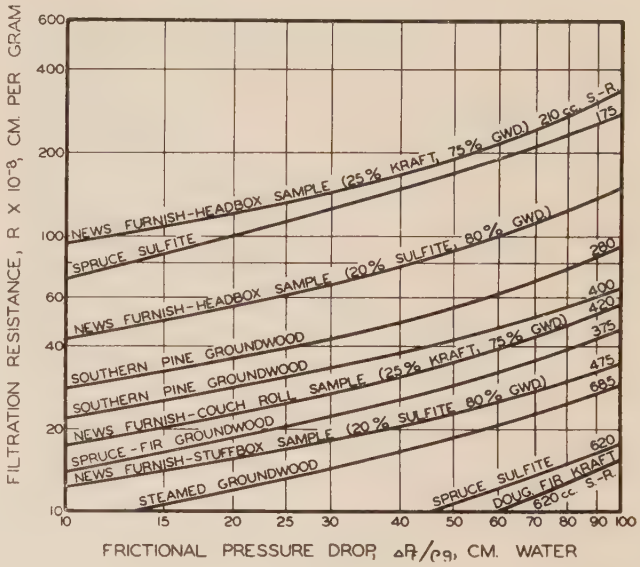

Fig. 8. Average specific filtration resistance—high range

Quantitative examples of porosity changes for differential elements of mass are shown in Fig. 6, and are based on the time-pressure drop relationship for a constant-rate filtration and for a constant-pressure filtration commencing at a pressure drop of 90 cm. of water. It is easily seen from Fig. 6 that the rate of change of porosity (and hence, the rate of loading) is similar for all differential elements within a constant-rate filter bed and is considerably more rapid than for any corresponding element in a constant-pressure bed. In the latter case, a considerable mass fraction of the entire pad undergoes a very slight change in porosity over the entire course of the constant-pressure period. Thus, this portion of the filter bed may be considered to be under a nearly constant load and would be expected to exhibit a creep effect of the type shown in Fig. 4.

In a series of constant-rate filtrations with the red oak kraft and other pulps, flow rates were varied over a nearly twofold range with a corresponding variation in the rate of loading of about threefold. No significant differences in the calculated values of filtration resistance were found. Thus, it appears that the rates of loading were fast enough in the constant-rate experiments to minimize the effects of creep, with the result that filtration resistances calculated from these experiments showed no time dependency. It appears logical to assume that the higher filtration resistances experienced in the constant-pressure filtrations were due to magnification of a creep effect at relatively low rates of loading of the filter bed elements.

The use of filtration resistance *per se* will usually involve systems in which the total pad weight and corresponding filtration times are relatively small, for example, in paper machine operation. The difficulties of interpreting the values of filtration resistance from constant-pressure experiments where time-dependency

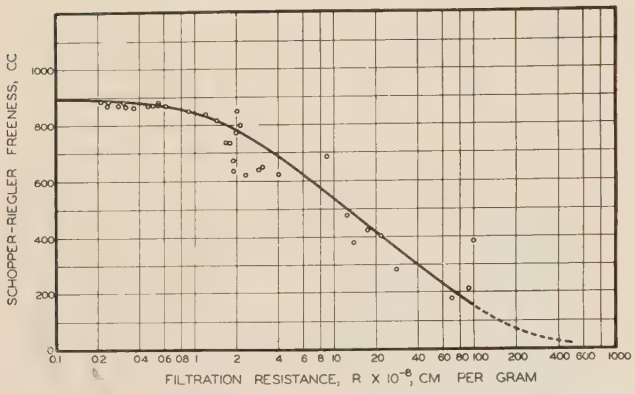

Fig. 9. Correlation of freeness and filtration resistance

appears to be an important variable are obvious. Hence, constant-rate filtrations, in which creep effects are minimized, is a preferred technique for determining the filtration resistance. The evaluation of specific surface and specific volume depends upon an analysis of the filtration data and compressibility measurements, in which creep effects are neglected. Again it is apparent that constant-rate filtrations give more reliable results than could be obtained from a constant-pressure method.

Finally, the speed, ease, and precision of the laboratory determination of filtration resistance and its components are far greater in the case of a constant-rate method than for a constant-pressure technique. Exclusive of sample preparation time, complete definition of the filtration resistance-pressure drop function of a given pulp may be completed in about 15 min. from one constant-rate measurement. To obtain similar (but much less precise) information with a constant-pressure technique necessitates at least three separate experiments requiring about 1 hr. each.

FILTRATION RESISTANCE

The average specific filtration resistance of a number of pulps is shown as a function of pressure drop in Figs. 7 and 8. The filtration resistances have arbitrarily been divided into a low range (Fig. 7) and a high range (Fig. 8). The low range indicates unbeaten and moderately beaten pulps while the high range filtration resistance curves include groundwoods and well or heavily beaten pulps. Data from both constant-rate and constant-pressure filtrations are included in these figures.

The vertical position of any one filtration resistance curve is fixed chiefly by the specific surface of the pulp, filtration resistance being proportional to the square of the specific surface. The slopes of the filtration resistance curves are determined mainly by the pulp compressibility and effective specific volume, larger values of both variables tending to increase the rate of change of resistance with pressure drop.

A comparison of specific surfaces as determined from filtration data and measured by the silvering technique (*14*) is shown in Table III. With the exception of the oak pulp, the specific surfaces of the unbeaten pulps

Table III. Specific Surface

	Freeness, ml. S.-R.	*Calculated from filtration data, specific surface, S, sq. cm./g.*	*Silvering technique,[a] specific surface, sq. cm./g.*
	Unbeaten Pulp		
Spruce Mitscherlich sulphite	870	13,780	12,600
Spruce sulphite	880	8,330	8,700
Southern pine kraft	865	9,140	9,500
Southern pine kraft (bleached)	885	10,630	10,000
Douglas-fir kraft (second growth)	870	10,170	9,700
Douglas-fir kraft (old growth)	885	8,560	8,700
Northern red oak kraft	870	13,300	16,400
Poplar soda	840	21,650	19,800
Poplar soda (bleached)	815	23,100	23,000
	Beaten Pulp		
Douglas-fir kraft	780	27,800	31,500
Douglas-fir kraft	620	33,700	36,300
Spruce sulphite	620	29,200	14,400
	Mechanical Pulp		
Southern pine groundwood	395	56,500	33,400
Spruce-fir groundwood	390	63,000	40,700

[a] Average of three determinations by Analytical Dept., The Institute of Paper Chemistry.

evaluated by the two methods agree within an average of 5%. In the case of a moderately beaten long fibered pulp (Douglas-fir kraft) with very few fines, the two methods agreed reasonably well. However, a beaten

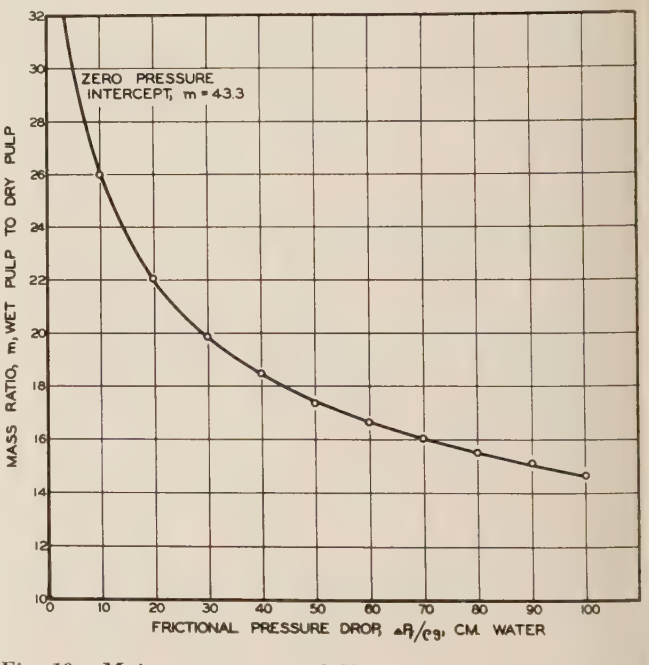

Fig. 10. Moisture content of filter bed of spruce sulphite pulp

spruce sulphite pulp and two groundwoods showed no agreement whatever, higher specific surfaces being exhibited for the filtration technique than for the silvering method. It must be concluded that the silvering values in these cases are spuriously low, since it is believed that no fiber property other than ex-

ternal surface area can account for the high filtration resistances shown for these pulps. Fines and fiber debris are known to cause difficulty in the silvering method (*14*, *15*). The close check between the two methods for unbeaten pulps with little or no fines gives support to the value used for the Kozeny constant for pulp fibers. Emerton and co-workers (*16*) reported fair agreement between unbeaten pulp specific surfaces determined by a permeability method (based on the Kozeny-Carman equation) and by the silvering technique, and presented data to show that the silvering method yielded too low values for beaten pulp specific surface.

Correlation with Freeness

Freeness and drainage time testers were designed to provide an index of pulp filtration resistance. In Fig. 9, Schopper-Riegler freeness is correlated with the average specific filtration resistance of the pulps shown in Figs. 7 and 8. To make the comparison as favorable as possible, the filtration resistance at a pressure drop of 10 cm. of water was used since this is the initial head in the Schopper-Riegler tester. The freenesses of unbeaten pulps approach a limiting value of about 890 ml. and in this high freeness range there is about a tenfold variation in filtration resistance for essentially the same freeness. In the freeness range of about 800 to 200 ml., pulps with the same filtration resistance show a spread of freeness as great as 250 ml. One would expect a good correlation of freeness and filtration resistance only for samples of the same pulp beaten according to the same schedule in the same refiner. Even in this case, the freeness test would still be almost completely insensitive in the high freeness range, and would tell little about the filtration resistance at some higher and perhaps more significant pressure drop. Clearly, the freeness test should be regarded, at best, as only a very rough and somewhat peculiar index of pulp filtration resistance. Campbell (*17*) has pointed out the inadequacies of freeness testers in the light of filtration

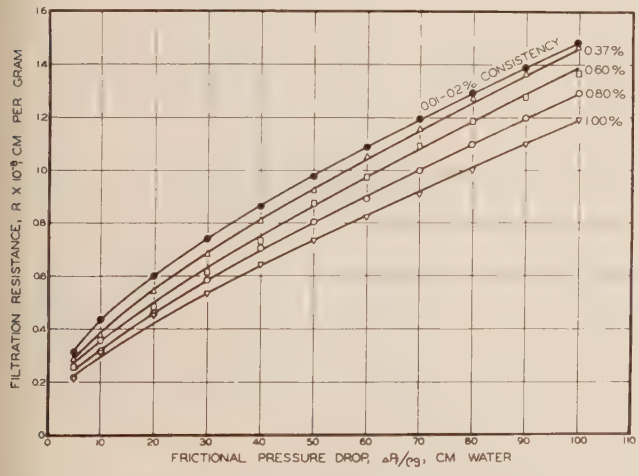

Fig. 11. Effect of slurry consistency on filtration resistance of spruce sulphite pulp

theory, particularly in regard to the conditions of falling head, loss of fines, and neglect of pulp mat compressibility and moisture content.

Pulp Filter Mat Moisture Content

Before studying the effect of slurry consistency on the specific filtration resistance, it was recognized that pulp filter mat moisture content data would be necessary for use in equation (2) at consistencies appreciably in excess of 0.01%. The following procedure was used for obtaining these data.

Pulp mats formed in constant-rate filtrations were allowed to expand at the end of the filtrations. A permeable piston was then inserted in the filtration tube so that its surface just contacted the face of the filter bed. Pad thicknesses were then measured with a cathetometer as water flowed through the pulp mat at constant-pressure drops. These pressure drops were increased in steps of 10 cm. of water from zero to 100 cm. of water. When a pressure drop of 100 cm. of water was reached, the permeable piston was fixed in position at the pad face and the system was closed by shutting the cock valve and pinching off the water manometer. At this point, when the flow of water was stopped, the filter mat readjusted to some uniform porosity, but in doing so, the over-all moisture content of the pulp-water system could not change (since the effective specific volume of the pulp was unaltered). Water was then sucked out of the top of the filtration tube to the level of the permeable piston. The pulp mat was transferred to a tared container and dried to constant weight at 105°C. The wet piston and wet septum were also weighed and corrections were made for any water introduced into the pulp pad from these sources. Knowing the moisture content of the pad at 100 cm. of water pressure drop, the moisture content at all lower pressure drops could be calculated from the pad thickness readings.

Moisture content data obtained in this manner are shown in Fig. 10 for a bleached spruce sulphite pulp. The data shown there are the average of six determinations made from constant-rate filtrations with slurry consistencies from 0.01 to 0.2%. The average moisture content of the pads at 100 cm. of water expressed as m, the mass ratio of wet pulp bed to dry pulp bed, was 14.55 with an average deviation from the mean of 3.5%.

It is important to note that the moisture contents of the filter beds may also be calculated from values of the effective specific volume of the pulp and knowledge of the wet pulp mat compressibility. This may be done in the following manner. The average porosity of a pulp filter bed under a given frictional pressure drop is

$$\epsilon_{av.} = 1 - vc_{av.} \qquad (15)$$

It can be show that the average filter mat concentration, $c_{av.}$, at some frictional pressure drop, ΔP_f, is given by,

$$c_{av.} = \frac{\int_0^{\Delta P_f} [(1 - vc)^3/c]\, dp}{\int_0^{\Delta P_f} [(1 - vc)^3/c^2]\, dp} \qquad (16)$$

$c_{av.}$ at a pressure drop of 100 cm. of water was calculated from equation (16) to be 0.0621 gram of pulp per cc. of filter bed. The average experimental value for c_{av} was 0.0565 gram per cc. with an average deviation from the mean of 6.5%. The value calculated from equation (16) was within 10% of the experimental value, and this was considered good agreement. The effective specific volume of the bleached sulphite pulp as determined from application of the differential form of the

Kozeny-Carman relationship to constant-rate filtration data was 1.67 cc. per gram of pulp. Using this value together with the calculated $c_{av.}$ value of 0.0621 gram per cc. in equation (15) gives an average porosity $\epsilon_{av.}$, of 0.896.

Water in the filter pad may be divided into two parts: water in the voids of the bed and immobilized water associated with the cellulose. The water associated with the cellulose is the difference between the effective specific volume of the fibers and the pycnometric specific volume of the fibers in water. Taking the pycnometric specific volume in water to be 0.62 cc. per gram (*18*), gives a value of the immobilized water associated with the cellulose of 1.05 cc. of water per gram of pulp. Then, for a unit volume of filter bed, the water in the voids is 0.896 gram (the average porosity) and the water with the cellulose is 1.05×0.0621 or 0.065 gram. This corresponds to a ratio of wet to dry pulp of 16.5, which agrees with the experimental value of 14.55 within 13%.

The good agreement between the experimentally measured moisture content and the value calculated from equations (15) and (16) is taken as strong evidence supporting the accuracy of the effective specific volume and the correctness of the Kozeny-Carman porosity function. Similar calculations could be made for other pulps at any desired pressure drop from constant-rate filtration data and wet pulp pad compressibility measurements.

Effect of Slurry Consistency

Constant-rate filtrations were made with the bleached spruce sulphite pulp discussed in the previous section over a slurry consistency range from 0.01 to 1.0%. The flow rates were reduced as slurry consistency was increased to maintain a filtration time of about 5 min. to reach a pressure drop of 100 cm. of water. When the moisture contents, as shown by Fig. 10, are substituted into equation (2), it can be seen that the water retained by the filter mat does not become an appreciable factor in the filtration calculations until a consistency of 0.1% is reached. Thus, the filtration resistances for slurry consistencies from 0.01 to 0.07% were calculated from the simplified equation (6), and for consistencies from 0.1 to 1%, equation (5) was used. The results of the constant-rate filtrations are shown in Fig. 11. No variation in filtration resistance was encountered for slurry consistencies of 0.01, 0.03, 0.05, 0.07, 0.10, and 0.20%. Thus, the filtration resistance curve over this range of consistencies represents the averaged data for these six filtrations. The average deviation of filtration resistance over a pressure range of 10 to 100 cm. of water for the six runs was 2.2%. This is greater than the error of less than 1% experienced for filtrations made at the standard slurry consistency of 0.01%, but it was found that the precision of the filtrations decreased as the consistencies were increased. The constancy of filtration resistance from 0.01 to 0.2% was surprising since fiber flocculation was observed to commence in the filtration tube at a consistency of 0.03% and increased rapidly until at 0.2% consistency the entire slurry suspension was grossly flocculated into irregularly shaped fiber masses several inches in diameter. Apparently the fiber flocs were consolidated into a homogeneous pad as the filter mat built up, with the result that there were no oversized pores in the pulp bed to contribute to a lowering of filtration resistance.

The data in Fig. 11 show a lowering of filtration resistance as the consistency is increased to 0.4, 0.6, 0.8, and 1%. On the average, over a pressure range of 5 to 100 cm. of water, filtration resistance decreased about 25% for an increase in consistency from 0.2 to 1%. This decrease in filtration resistance is considered a maximum for the particular pulp investigated, since it was observed during the filtrations that the fiber flocculation was at a maximum. The flow rates in the filtrations from 0.1 to 1% were in such a range that no turbulence was present in the slurry suspensions and there was no fiber motion relative to the flow of water. The turbulence in the constant head section of the filtration tube caused by the introduction of slurry was localized at the point of entrance and was quickly damped out by the main body of slurry.

Although no visual line of demarcation between the pulp filter mat and pulp slurry was present at consistencies above 0.1%, such a point exists provided slurry consistency does not exceed the zero compacting pressure pad concentration, i.e., the mat concentration at the pad face. The average experimental value of the zero pressure pad concentration, obtained in connection with the filter mat moisture content measurements, was 0.023 gram per cc. The result obtained by extrapolation of the porosity distribution curves was 0.018 gram per cc. The true filter bed concentration at its face was probably intermediate between these values. Thus, at a slurry consistency of approximately 2% the process of water removal would be one of thickening instead of filtration.

The amount of water retained by the filter mat

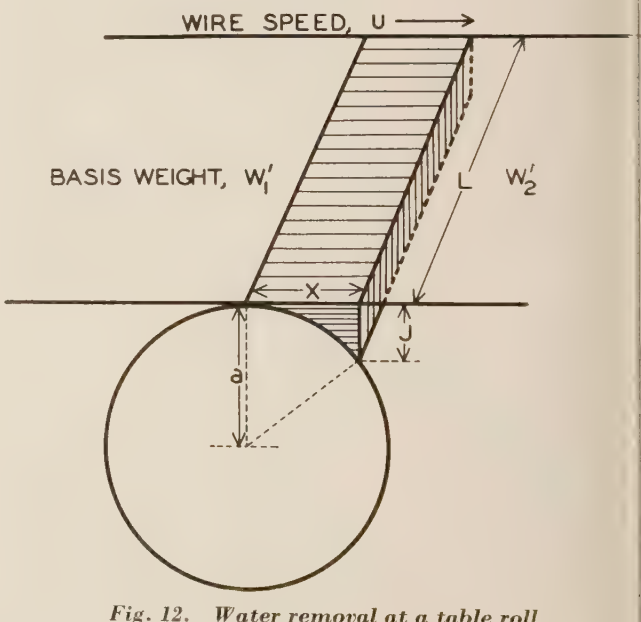

Fig. 12. Water removal at a table roll

becomes a very important factor in calculating filtration resistance in the slurry consistency range of 0.1 to 1%. The higher the slurry consistency, the more important it becomes to account for this water in the filter mat. For example, had this water been neglected in the constant-rate filtration calculations at a slurry

consistency of 1%, the values of filtration resistance would have been 120% higher at 10 cm. of water pressure drop and 35% higher at 100 cm. of water than those shown in Fig. 11.

Application to Paper Machine Drainage

Wrist (*19*) and later Hendry (*20*) considered water removal on the table roll section of a fourdrinier machine as a problem in filtration, and developed essentially similar drainage equations expressing the rate of water removal at a table roll chiefly in terms of the roll radius, machine speed, and total filtration resistance. Recognizing the importance of the pressure differential causing drainage, Wrist directly measured the suction at a table roll nip of a laboratory model machine over a speed range of 140 to 550 f.p.m. The experimental results agreed remarkedly well with those predicted by an approximate force balance in which the term of greatest magnitude was $^1/_2(\rho u^2)$, where u is the machine speed. Thus, if one neglects the relatively small static head of the slurry on the wire, as a first approximation, the frictional pressure drop across the pulp mat as water drains into the table roll nip is given by this "velocity head" term.

A simplified, and purposely exaggerated, sketch of the drainage area at a table roll is shown in Fig. 12. Assuming, as Wrist's data would indicate, that drainage over the distance x is at constant pressure, an expression for the rate of water removal at a table roll may be developed as follows. The filtration rate equation [equation (1)] may be written for a small area per unit width of wire, δx, and integrated over distance x to give,

$$q = \frac{x\ \Delta P_f}{\mu W'_{\text{av.}} R} \qquad (17)$$

where q is the volumetric drainage rate per unit width of wire. The average basis weight of the pulp mat, $W'_{\text{av.}}$, is defined as the arithmetic average of the mass of fibers in the filter bed per unit area entering and leaving the drainage area. Thus,

$$W'_{\text{av.}} = \frac{W_1' + W_2'}{2} \qquad (18)$$

Since the height of the nip, J, is relatively small, the geometry of the system shows that,

$$x^2 \cong 2aJ \qquad (19)$$

where a is the table roll radius, and

$$q \cong uJ \qquad (20)$$

Both equations (19) and (20) were used by Wrist (*19*) and by Hendry (*20*) in their development of drainage relationships, and the equations may be combined to eliminate the height of the nip, J, to give the drainage area per unit width of wire, x, in terms of measurable quantities:

$$x = \left[\frac{2aq}{u}\right]^{1/2} \qquad (21)$$

Substituting equation (21) in equation (17) gives:

$$q = \left[\frac{2a}{u}\right]\left[\frac{\Delta P_f}{\mu W'_{\text{av.}} R}\right]^2 \qquad (22)$$

This expression is equivalent to those given by Wrist and by Hendry except for a numerical factor of 4. These authors also preferred to combine the viscosity of the filtrate and the average specific filtration resistance into a total resistance term.

Since the average specific filtration resistance, R, is a function of the pressure drop, and, as found by Wrist, $\Delta P_f = {}^1/_2(\rho u^2)$, then filtration resistance is indirectly a function of machine speed, u. Knowing the frictional pressure drop across the sheet for a given machine speed, equation (22) may be used in connection with paper machine drainage data to calculate the average specific filtration resistance of a pulp by evaluating $W'_{\text{av.}}$ from equations (2) and (18). Wrist showed the total drainage resistance as a function of the calculated sheet weight over the table roll section of a fourdrinier machine, and argued that the nonlinearity of the relationship precluded the concept of a specific filtration resistance. However, his data show that the increase in average specific filtration resistance along the table roll section was only about 15%. Most of this increase in resistance was probably due to a greater retention of fines as the sheet thickness increased.

Once the validity of paper machine drainage relationships such as given in equation (22) can be established, and knowledge of the suction at a table roll is explored over wide ranges of machine speed, the utility of the relationships will depend primarily on the ability to obtain laboratory evaluations of pulp filtration resistance. There would appear to be considerable promise to the concept and measurement of an average specific filtration resistance as discussed in this paper.

When measured on a whole pulp at a slurry consistency free from flocculation effects, filtration resistance may be defined as the maximum possible value to be expected on the machine wire. The related effects of pulp flocculation and loss of fines experienced in actual machine operation will result in lower filtration resistances which will probably be primarily a function of the individual paper machine operating variables. The influence of these important variables can probably be best interpreted in the light of the laboratory defined and measured maximum filtration resistance. Furthermore, the three important pulp properties of specific surface, specific volume, and compressibility serve to define completely a maximum filtration resistance. Knowledge of the influence of these physical properties on ultimate sheet strength may assist in the selection of optimum pulping and refining conditions that represent a maximum development of strength for certain desired levels of filtration resistance.

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Quantitative Studies of Water Removal by Table Rolls

W. E. BENNETT

The lengths of fourdrinier tables have not increased in step with increases of machine speed. Consequently forces other than those due to gravity act to produce drainage. Measurements of machine operating conditions, with stock tests, backwater flow rates and consistencies were taken on a medium speed machine making newsprint. Thirty-four such sets of data were obtained in the course of a wire life and from them the complete machine flow sheets calculated for various operating conditions. Multiple linear regression analysis was used to find the effect of a change of wire speed, temperature, consistency, freeness, and other empirical stock tests on drainage at different parts of the table. Speed had the largest effect, acting on the first part of the table. Temperature affected the last part of the table and measured stock properties had little influence over the range of the experiment. A theory by Wrist predicts large suction forces at high speeds in the nip of a table roll. These forces were confirmed experimentally and used to interpret the statistical analysis. Drainage is not a gentle, continuous process but is caused by short slugs of suction and this fact must be considered when devising empirical stock tests.

THE papermaking machine now called the fourdrinier originated at the time of the French Revolution and in a remarkably short time the essential features, as we know them today, had been developed. It is easy to forget, when looking at our huge modern machines, that there has been no fundamental change of design during the last century. The size and operating speeds of machines have increased gradually and this development has been governed by mechanical and electrical engineering considerations and the accumulated experience of papermakers. Changes have been tentative and empirical rather than as the result of calculation, for very little is known about the drainage of stock on the fourdrinier table which is of value to a designer. The position is rather like that of a man trying to design a steam locomotive without any knowledge of the theory of heat engines or the properties of steam.

Some of the problems become apparent when the historical development of the machine is considered. The Bryan Donkin machine of 1808, generally regarded as the first to be operated as a commercial success, had a wire 25 ft. long and could be operated at speeds of up to 37 f.p.m. Speeds have increased fiftyfold since that time and yet the length of the wire has only increased by a factor of 3 or 4. This fact is sufficient to suggest that drainage of stock on the wire is caused by something more than gravity forces. The drainage time in the standard handsheet machine does not depend upon whether the sheet machine is at rest or is moving horizontally at 20 m.p.h. If we could imagine a newsprint machine with a perfectly horizontal but unsupported wire between the breast roll and the couch it would have to be several hundred yards long if it were to travel at 1500 f.p.m. The very fact that it is supported by table rolls makes it possible to use a relatively short wire. This simple argument has overlooked the effect of suction boxes but even allowing for them it seems that table rolls have two functions. They support the wire and also extract water at the higher speeds.

Water extraction can be too fast at the early rolls of a fast machine. In an attempt to get the stock further down the wire and help formation it has been found necessary to introduce grooved table rolls, dandy-type table rolls, forming boards, and in some cases to remove a table roll altogether.

Another problem is that of predicting how a stock will behave on the wire on the basis of empirical tests such as freeness. On slow machines the freeness of the stock is often the criterion of operating speed but at higher speeds freeness becomes a less satisfactory concept. Indeed it is the experience of more than one newsprint mill to have put up the speed of their machines and yet work with a "wetter" stock as measured by freeness.

These facts are sufficient to show that drainage on the wire is not a simple process and needs careful study if useful information is ultimately to be provided for the design of new machines. The physics of water removal is being studied by the staff of the British Paper and Board Industry Research Association and this paper is an interim report of the work.

EXPERIMENTAL WORK

There are two main questions to answer: (1) how is water removal influenced by the construction and operation of the wet end, and (2) can water removal be predicted from a knowledge of stock properties?

It was decided to begin the work by taking a series of measurements on a papermaking machine rather than to attempt to dissect the problems for study in

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the laboratory, as the latter approach offered too many blind alleys. All the work has related to newsprint manufacture and the interest has been in water removal alone, not in formation.

In 1937 Scott (*1*) reported a series of measurements of drainage from the table rolls and suction boxes of a newsprint machine and this work was taken as a model. Our experiments were carried out at the Grimsby, England, mill of Peter Dixon & Sons Ltd., on a machine running at about 700 f.p.m.

A metal trough, 1 ft. wide, was fitted under the wire to the machine frame. It ran from the breast roll to

Fig. 1. Collecting trough fitted to machine frame

the suction boxes and was compartmented so that the flow from each roll could be collected and metered separately. Figure 1 shows a section of this tray with baffles erected between the rolls. The 21 table rolls are situated about 12 in. apart and are 7 in. in diameter.

A set of measurements comprised the flow, consistency, and ash content of the discharge from each roll and suction box except for the breast roll and first table roll where the flow could not be separated. The flow through the suction boxes was measured by a chemical dilution method and the extraction at the couch was estimated from a knowledge of the basis weight and moisture content of the web before and after the couch. Samples were taken from the flow box, headbox (thick stock) and pit, and on these, measurements were made of consistency, ash content, pH, freeness, and fiber length index wherever possible. The operating conditions of the machine were recorded, including wire speed, suction box vacuum, stock height, slice opening, stock temperature, and power consumption.

The experimental methods will not be described in detail as they will be found in a previous paper (*2*). Ideally, all the machine measurements had to be made simultaneously but in fact they took about 20 min. using a team of seven to ten observers. The stock tests took 2 to 3 hr. to complete. For some of these, rapid methods had to be developed. Some tests had to be reluctantly ruled out because of time considerations, for instance fiber fractionation and aluminum ion concentration of the fibers. The limitation of accuracy was that of the flow measurements and all other determinations were made to at least this precision.

These measurements were done at least once a day throughout the life of a wire and 34 sets were obtained for the first experiment. No attempt was made to influence the operation of the machine and throughout the experiment paper was being made in the usual way.

The ranges covered by the readings were: wire speed 609–692 f.p.m.; consistency in flow box 0.67–0.88%; Canadian Standard freeness in flow box 43–59; temperature 25–38° C., and flow from all table rolls 92–116 imperial gal. per ft. width per min.

MATERIAL BALANCE

Since it was intended to do a considerable amount of analysis of the results, a check on the possibility of occurrence of gross error was necessary. This could be done by collecting the results in tabular form so that, say, the drainage from roll 11 could be easily checked by eye from one run to the next. However, instead of merely reporting the measured quantities, they were transformed into rates of flow of water and solids at all points of the machine. This allowed various checks to be made, a balance of materials to be struck.

A simplified flow diagram for the machine is given in Fig. 2 and it is seen that, assuming no loss of solids from the sheet in the drying and press sections, the moisture-free basis weight and the reel speed will give the rate of production of solids at the couch.

The weight of solids leaving the couch plus an assumed value for the extraction rate at the couch give the weight of solids approaching the couch. For each suction box and table roll the rate of extraction of the backwater and the consistency of the water at each point give the solids extracted by the boxes and rolls. The solids extraction rates can now be accumulated up

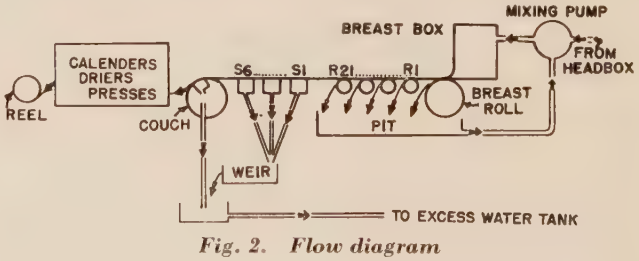


Fig. 2. Flow diagram

the table, giving the weight of solids in the stock on the wire at any point.

An average value for the moisture content of the sheet on the wire approaching the couch and the solids in the sheet at this point gives the weight of water in the sheet, and, in a similar manner to that for the solids, the backwater extraction rates are accumulated, giving the total water on the wire at all points.

Owing to the mechanical construction of the couch it was not possible to measure the water extraction by the method used for the suction boxes, hence the assumptions in the procedure outlined above.

Ash content determinations on the consistency samples have been used as a measure of the clay content at

points on the machine. The calculations are similar to those using backwater consistencies.

From Fig. 2 it can be seen that certain values can be checked. For example, the water approaching the breast roll is equal to the water leaving the slice which can be determined from a knowledge of the slice opening, the height of the stock in the flow box, and a slice discharge coefficient. Also the consistency of the backwater measured in the pit is equal to the mean roll extraction consistency weighted by the appropriate flow rates. A similar check exists for the individual and combined suction box backwater which can be sampled as it passes through a weir box.

A third check used on the data is that if the consistencies of the stocks entering and leaving the mixing pump are known and, in addition, if the rate of flow from the pump is known, then this rate can be divided in the correct proportions into the flows from the headbox and the pit. The pit flow calculated by this means should equal the total extraction rate of the table rolls and the flow from the headbox should equal the rate of flow of water on the wire leaving the last table roll. Similar checks can be made with the solid and ash flow rates.

These checks should be exact for an ideal system with no measuring error. This state of affairs does not exist in practice and these values are given in the tables only as checks against gross errors.

Table I is an example of one of the 34 sets of readings expressed in the form described, together with some of the associated measurements of stock and machine conditions.

The first column gives the position on the machine at which the measurements were taken (see Fig. 2) as follows:

MP HB	Headbox stock entering mixing pump
MP Pit	Table roll backwater from pit entering mixing pump
BB	Breast box
BR + R1	Breast roll plus roll 1 (owing to space limitations these positions had to be measured together)
R2–R21	Roll 2 to roll 21
Pit	Table roll backwater
S1–S6	Suction box 1 to suction box 6
Weir	Suction box backwater (total)
Couch	
Press	
Reel	

Columns A and B give the rate at which solids are approaching each part and the rate at which the solids are being extracted in the backwater from each part. Similarly, C and D give the weight of the ash which is used as a measure of the clay content. Columns E and F give the volume rates of water approaching and discharging for the table roll section and the weight rates for the suction boxes and onward.

The first part of column G is the height of the stock on the wire approaching each roll and the latter part is the extraction rate in gallons per minute for the whole width of each suction box (13.2 ft.). All the values of flow rates in columns A to F are reduced to an average foot width of the machine.

The discharge consistencies in columns H, I, and J are defined as the weight of material in 100 ml. of stock or backwater. The ash consistency is obtained from the pads formed during the total solids consistency determination and the fiber consistency by subtraction of the ash from the total solids.

The following general points should be noted:

1. Values in italics are assumed values, e.g., single consistency determinations lost have been filled in by interpolation.
2. Values in brackets are obtained by calculation from the data and give a check against gross error of the measured values which are given immediately above the ones in brackets.
3. The symbol Σ indicates an arithmetic total of the column above it.

It is seen that the drainage rate decreases rapidly over the first few rolls and then more slowly as filtration is retarded by the forming sheet. Roll 1 removes about $2^1/_2$ times as much as does roll 2 and this roll removes as much as do the last six rolls on the table.

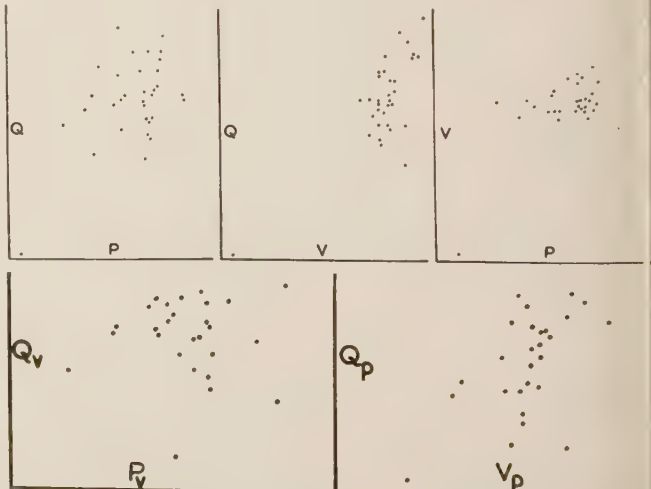
A peculiar feature of the averaged drainage behavior of the rolls is that 4, 16, and 19 take out more water than is expected. In the particular run instanced, roll 15 removes 2.27, roll 16 removes 2.36, and roll 17 removes 2.16 gal. per min. per ft. width. This is not just a random variation for the effect was noticed in experiments carried out nearly 2 years later and was not affected by trimming the roll and even replacing it. No certain explanation has been found but it is possibly due to waves of vibration propagated along the wire from the suction boxes.

METHODS OF ANALYSIS

In an experiment of the type described the measured drainage rate will be influenced by many factors and the object of the analysis must be to show the separate influence of these factors on drainage. This is, in theory, possible by statistical techniques but practical considerations limit the number of factors which can be analyzed at any one time to six or eight. Graphical methods become far too cumbersome.

Dot Diagrams

Consider the 34 measurements of drainage rate at, say, roll no. 2. Figure 3 shows the drainage rate, Q, plotted against the corresponding values for the consistency on the wire, P, at roll 2, and the dots indicate that a correlation exists between Q and P, ignoring the effects of other variables. However, Fig. 4 shows a high correlation between Q and V (speed), and Fig. 5 shows a high correlation between V



Figs. 3–5 (top) and 6–7 (bottom). Dot diagrams of relations between drainage Q, consistency P, and speed V at second table roll

and P. The latter is, of course, a consequence of the actions of the machine operator trying to keep a steady sheet weight. This leads one to suspect that the correlation in Fig. 3 may be due not only to a direct dependence between drainage and consistency but also to the manner in which, in the data, changes in consistency follow those of speed, and if speed variations could be allowed for the relationship might be quite different. There are graphical methods of carrying this out (*3*) and the relationships between consistency and drainage, with speed variations eliminated, and between speed and drainage, with consistency variations eliminated, are shown in Figs. 6 and 7. The correlation between drainage and consistency has mostly

Table I. Example of Flow Data Sheet for All Points on the Fourdrinier

	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*
	Total solids, lb./min./ft. width		*Ash, lb./min./ft. width*		*Water, gal./min./ft. width*		*Head on wire, ft.*	*Discharge consistencies, %*		
	Stock on wire approaching	*Back water discharged*	*Stock on wire approaching*	*Back water discharged*	*Stock on wire approaching*	*Back water discharged*	*Stock on wire approaching*	*Total solids*	*Fiber*	*Ash*
MP HB	6.23	...	0.64	...	20.3	...	...	3.07	2.76	0.313
MP Pit	5.68	...	1.67	...	117.3	...	...	0.407	0.258	0.149
BB	...	...	..	...	...	...	...	0.799	0.634	0.165
								(0.866)	(0.698)	(0.168)
BR + R1	11.91	1.185	2.31	0.416	137.6	26.5	0.0324	0.447	0.290	0.157
R2	10.72	0.612	1.89	0.216	111.1	13.5	0.0262	0.453	0.293	0.160
R3	10.11	0.369	1.68	0.137	97.6	8.61	0.0230	0.429	0.270	0.159
R4	9.74	0.288	1.54	0.108	89.0	6.95	0.0210	0.414	0.258	0.156
R5	9.45	0.229	1.43	0.087	82.1	5.50	0.0194	0.417	0.259	0.158
R6	9.22	0.187	1.35	0.071	76.6	4.66	0.0181	0 401	0.249	0.152
R7	9.04	0.170	1.28	0.065	71.9	4.03	0.0170	0.421	0.259	0.162
R8	8.87	0.152	1.21	0.060	67.9	3.57	0.0160	0.426	0.259	0.167
R9	8.71	0.132	1.15	0.052	64.3	3.16	0.0152	0.417	0.254	0.163
R10	8.58	0.125	1.10	0.048	61.1	3.16	0.0144	0.397	0.244	0.153
R11	8.46	0.118	1.05	0.047	58.0	3.01	0.0137	0.393	0.238	0.155
R12	8.34	0.109	1.00	0.042	55.0	2.81	0.0130	0.388	0.238	0.150
R13	8.23	0.099	0.96	0.039	52.2	2.58	0.0123	0.385	0.233	0.152
R14	8.13	0.094	0.92	0.037	49.6	2.46	0.0117	0.384	0.232	0.152
R15	8.04	0.087	0.89	0.035	47.1	... 2.27	0.0111	0.383	0.231	0.152
R16	7.95	0.092	0.85	0.038	44.9	2.36	0.0106	0.390	0.230	0.160
R17	7.86	0.084	0.81	0.035	42.5	2.16	0.0100	0.388	0.228	0.160
R18	7.77	0.076	0.78	0.031	40.3	1.99	0.0095	0.383	0.227	0.156
R19	7.70	0.072	0.75	0.030	38.3	1.86	0.0090	0.385	0.226	0.159
R20	7.63	0.073	0.72	0.031	36.5	1.93	0.0086	0.380	0.219	0.161
R21	7.55	0.065	0.69	0.026	34.5	1.75	0.0082	0.374	0.223	0.151
Pit		ϵ4.42		ϵ1.65		ϵ104.8		0.407	0.258	0.149
								(0.422)	(0.265)	(0.157)
					Water, lb./min./ft. width		*Total S.B. flow, gal./min.*			
S1	7.49	0.210	0.66	0.101	328.0	97.7	129.0	0.215	0.112	0.103
S2	7.28	0.042	0.56	0.026	230.3	47.8	63.1	0.087	0.032	0.055
S3	7.24	0.078	0.53	0.040	182.5	55.2	72.9	0.141	0.069	0.072
S4	7.16	0.036	0.49	0.020	127.3	43.3	57.1	0.082	0.036	0.046
S5	7.12	0.016	0.47	0.009	84.0	21.7	28.6	0.072	0.031	0.041
S6	7.11	0.006	0.46	0.004	62.3	7.7	10.2	0.084	0.036	0.048
Weir		ϵ0.387		ϵ0.199		ϵ273.4	ϵ360.9	0.147	0.074	0.073
Couch	7.10	*0.01*	0.46	*0.01*	54.6	23.7		(0.142)	(0.069)	(0.073)
Press	7.09		0.45		30.9					
Reel	7.09									

Stock Tests:

Headbox: C.S.F., 136°; S.R., 60.4°; D.T., 16.0 sec.; F.L.I., 125 mgm.

Flow box: C.S.F., 49°; S.R., 76.75°; D.T., 56.15 sec.; F.L.I., 77 mgm.

Flow box:

Height of stock, 20.25 in.
Slice opening, 0.488 in.
Slice flow (C = 0.9), 142.7 gal./min./ft. width
Temperature, 36.7°C.
Soap No., 19.5 ml.
pH, 4.8

Pit:

pH, 4.9

Suction Boxes and Couch:

Front side pressure, in. Hg: S.B.1, 0.95; S.B.2, 0.93; S.B.3, 1.25; S.B.4, 2.30; S.B.5, 3.85; S.B.6, 4.30–4.50; Couch, 16.6

Back side pressure, in. Hg: S.B.1, 3.4; S.B.2, 1.3; S.B.3, 2.5; S.B.4, 3.2; S.B.5, 3.5; S.B.6, 3.6; Couch, 14.9

After couch moisture content, 81.35%
After couch ash content, 6.32%

Wire:

Hours run, 483½ hr.
Speed, 681 f.p.m.
Set line, R12–R13
Dry line, S2–S3

Reel:

Basis weight (moisture-free), 48.71 g./sq. m.
Speed, 711 f.p.m.

Power consumption:

Supply voltage, 239.2 volts
Screens, 18.6 amp.
Suction box vacuum, 62.6 amp.
Mixing pump, 62.2 amp.
Excess water and sprays, 70.0 amp.
Couch vacuum, 294 amp.
Press vacuum, 257 amp.
Lickup vacuum, 124 amp.
Machine drive, 1030 amp.

disappeared, showing that the apparent relationship shown in Fig. 3 was due to the influence of speed. The speed-drainage relationship is as strong as before. This treatment of dot diagrams can be extended to further factors; temperature, for instance, could be eliminated and as the process continues certain of the relationships are likely to strengthen, others to become more diffuse. But it is a very tedious business and is unnecessary, as the results can be calculated without the aid of diagrams.

Regression Analysis

It appears that the relationship between speed and drainage shown in Fig. 7 could be expressed by a straight line through the points, of the general form

$$y = a + bx$$

The deviations of the points from this line will be the result of unconsidered factors and errors of measurements. The line of best fit or regression line can be calculated and is obtained by minimizing the sums of squares of the deviations of the points from the regression line. This condition is satisfied when

$$b = \frac{\Sigma(xy)}{\Sigma x^2}$$

where Σ means "the sum of," and b is then called the regression coefficient.

The deviation of an individual value y from the mean value for the set, $\bar{y}$, can be regarded in two parts, the deviation of y from the regression line, y_d, and the deviation of the corresponding ordinate on the regression line from the mean value, y_e, and it can be shown that

$$\Sigma y^2 = \Sigma y_e^2 + \Sigma y_d^2$$

This apportioning of the variability of the readings as being partly due to the regression line and partly due to the deviations about the regression line leads to a test of significance for the regression coefficient. The coefficients of the regression line calculated from the 34 points have definite values but they are only to be taken as *estimates*. If another similar set of data was available the coefficients would be different. Significance tests are used to establish that the value of a coefficient is really different from zero and to find the probability that it will lie between certain limits. The ratio of Σy_d^2 to Σy_e^2, weighted by the corresponding degrees of freedom, is a measure of the significance of the regression coefficient. In alternative language, if the scatter of the points about the regression line is high the relationship implied between the two factors is of doubtful accuracy and there is perhaps little point in looking for a physical explanation of the equation.

The procedure for simple linear regression can be extended to cover more than two factors, and is then known as *multiple linear regression*, the values being partial regression coefficients. The prediction equation is of the form

$$y = a + b_1x_1 + b_2x_2 + \ldots b_px_p$$

and, as before, to find the partial regression coefficients b_1, b_2, etc., it is required to minimize the sums of the squares of the deviations of the points from the multiple regression, i.e.,

$$\Sigma(y - b_1x_1 - b_2x_2 - \ldots - b_xx_p)^2$$

This entails solving a set of p simultaneous equations,

$$\begin{aligned} b_1\Sigma x_1^2 &+ b_2\Sigma x_1x_2 + \ldots + b_p\Sigma x_1x_p = \Sigma x_1y \\ b_1\Sigma x_1x_2 &+ b_2\Sigma x_2^2 + \ldots + b_p\Sigma x_2x_p = \Sigma x_2y \\ &\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ b_1\Sigma x_1x_p &+ b_2\Sigma x_2x_p + \ldots + b_p\Sigma x_p^2 = \Sigma x_py \end{aligned}$$

for the partial regression coefficients b_1, b_2. . .b_p.

The most convenient way of doing this is to calculate an inverse matrix and a skilled computer with a desk machine can compute and check a multiple regression of six factors in about 3 hr.

These remarks can only indicate the methods of regression analysis, their uses and limitations. For details, reference should be made to standard textbooks (*4*).

SOME RESULTS OF THE ANALYSIS

As a first step the flow from each table roll was considered separately and the relation between drainage rate and six of the machine and stock conditions was estimated for each of the 21 table rolls in turn, using multiple regression analysis. The results are shown in Table II.

Six factors were chosen: wire speed, temperature, flow box consistency, Canadian Standard freeness, sheet machine drainage time, and fiber length index. The figures in the columns are not the actual regression coefficients which are required for the prediction equation mentioned in the last section, but are expressed as proportions of the mean, i.e., each give the percentage change in drainage rate resulting from a 1% increase of the variable at the head of the column. Coefficients which differ significantly from zero are marked with one or two asterisks, denoting significance at the 5 or 1% level. The values without an asterisk are insignificant and this means that, as far as can be judged from the data by this particular analysis, they have no real effect on drainage. The last column is a measure of the variability of the drainage readings, expressed as a coefficient of variation, which is unaccounted for after taking out the influence of the factors. This is made up of the sampling error and the average experimental error of measuring flow, the latter being between 2 and $2^1/_2$%. Where it differs greatly from this, as in the case of roll 3, either the flow measurements at roll 3 were subject to errors greater than the average, or some factor influencing drainage, other than the ones considered, was at work. It is believed that the flow measurements were responsible.

The lower the residual coefficient of variation, the more likely it is for a factor to show up as significant. According to the table, the most important single factor is speed. There is a significant effect at most of the early rolls and it is probable that the effect at rolls 3, 4, and 5 would be significant if it were not for the high coefficients of variation.

The effect of temperature is mainly shown from roll 10, onward, a rise of temperature producing a faster drainage.

The effects of the other four factors are less apparent. Flow box consistency has insignificant effects at every roll, although the fact that most of them are negative indicates a bias as a whole and it is likely that consistency has an effect but is too small to be detected in the present data. Similarly sheet machine drainage time has a series of negative values over the second

Table II. Drainage Rates from Table Rolls—Effect of Machine and Stock Variables

Roll no.	Mean rate of flow	Temperature, T	C.S.F., F	Speed, V	Drainage time, G	F.L. index, I	Consistency, P	Residual coefficient of variation, %
1	31.7	0.354	0.060	−0.210	0.302	0.043	−0.523	4.4
2	12.7	0.164	0.352	2.769[a]	−0.006	−0.016	−0.159	5.2
3	8.25	0.994	0.680	1.328	0.365	−0.296	−1.102	9.9
4	7.09	−0.547	0.286	2.311	0.236	0.039	0.301	6.6
5	5.38	0.579	0.139	1.429	0.048	0.286	−0.023	6.9
6	4.74	0.024	0.118	2.041[a]	0.079	0.044	−0.041	2.1
7	4.16	2.44[a]	0.076	1.326[a]	0.112	0.142	−0.079	2.1
8	3.83	−0.221	0.322[b]	1.684[a]	0.177	−0.051	−0.120	3.5
9	3.41	0.307	−0.290[b]	−0.449	−0.308[b]	0.169	0.328	3.1
10	2.98	0.484[a]	0.159	1.179[a]	−0.001	−0.138	−0.289	2.8
11	2.75	0.592[a]	0.486[a]	1.133[a]	0.047	−0.006	−0.384	3.6
12	2.71	0.422[b]	−0.001	0.939[a]	−0.121	−0.152	−0.412	3.4
13	2.50	0.198	−0.007	0.841[a]	−0.108	0.005	0.012	3.0
14	2.41	0.469[b]	0.032	−0.246	−0.137	0.039	−0.007	3.0
15	2.19	0.560[a]	0.165	0.287	−0.035	−0.079	−0.201	2.7
16	2.37	0.350	−0.098	−0.092	−0.219	−0.078	−0.048	3.8
17	2.12	0.302	−0.090	0.513	−0.089	0.034	0.085	3.2
18	2.00	0.621[b]	0.118	−0.195	−0.023	−0.010	−0.268	4.7
19	2.06	0.174	0.096	0.986	−0.147	−0.092	−0.532	4.0
20	1.85	0.624[b]	0.254	−0.461	−0.063	0.179	0.110	4.3
21	1.76	0.744[a]	0.155	−0.257	−0.229	−0.343	−0.502	3.9
Total	109.0	0.328[b]	0.194	0.895[a]	0.089	−0.035	−0.365	2.2

[a] Significant at 1% level.
[b] Significant at 5% level.

half of the table, leaving one to suspect a relationship without being able to prove it. Freeness has eight positive coefficients at the beginning of the table, all but one insignificant, suggesting that at this part of the table, if at all, freeness would be effective. Fiber length index appears to be without effect over the whole table.

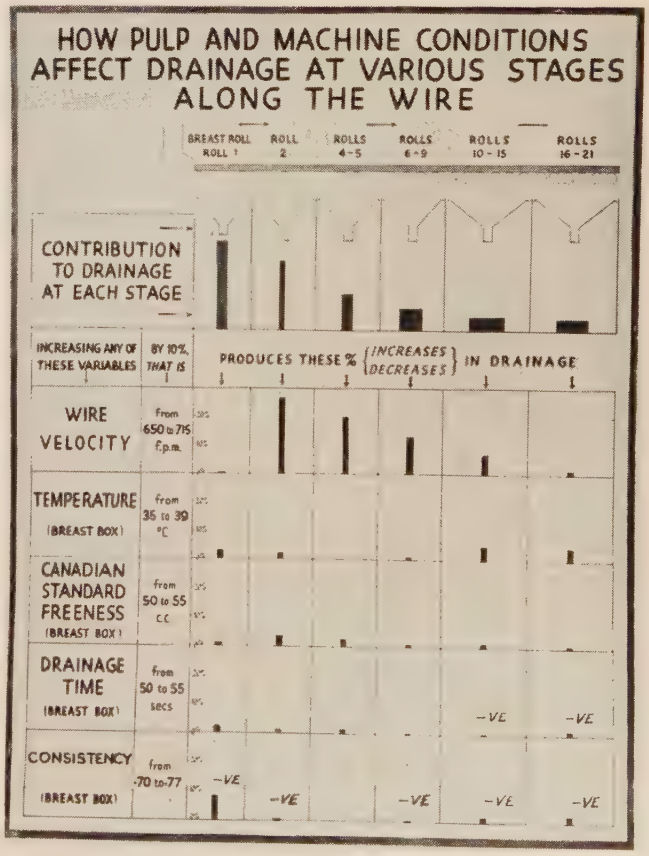
All these facts suggest that, as the sheet travels down the wire, the drainage process passes through two or more phases and that one factor will be important over a group of rolls but not at others. A more simple picture would be obtained if instead of studying the effects of the rolls individually, they were grouped together. This has been done in Table III. The spacing of the rolls shown in the table is for convenience. On the machine they were spaced evenly. The average rates of flow of the groups of rolls are denoted by the areas, which are roughly the same, except that for the breast roll and roll 1 together, which is twice as great as the others. Roll 3 has been omitted from this table because of its anomalous behavior.

THEORIES OF DRAINAGE AND THE EFFECT OF SPEED

The analysis has shown that by far the largest factor influencing drainage is that of speed. At roll 2, an increase of speed from 650 to 715 f.p.m., i.e., of 10%, produces an increase of drainage of more than 20%. The effect is strong at the early rolls and decreases toward the drier end. For a constant consistency in the flow box, as the speed increases, the consistency achieved on the wire will actually increase at the early rolls but it becomes more difficult to extract the water at the later rolls. Considering the table as a whole, an increase of speed results in about the same percentage increase in drainage. The results show that water does not drain by gravity, or at least that this is not the major effect.

Consider the $^1/_2$ in. of stock on unit area of wire leaving the slice and assume, when that area of wire arrives at the suction boxes, all the water has drained away as the result of gravity forces. If the speed is now increased by a small increment, that element of area now reaches the suction boxes in a shorter time, all the water has not drained away and some is carried over to the suction boxes. At the high speed the drainage into the pit from any single area of wire will be less than at the low speed. However, in any given time interval, at higher speeds more elements of area will pass the slice and the drainage from these extra elements will more than compensate for the water carried over to the boxes. Therefore as the speed goes up more water is drained into the pit, but the rate is considerably

Table III



less than a direct percentage. A consequence therefore of gravity drainage is that if the speed increases by 10% the water drained into a pit will increase by something much less than 10%. Yet the analysis shows that a 10% increase of speed results in a 25% increase of drainage at roll 2.

The only theory of drainage published at the time when this experiment was carried out was that due to Cowan (*5*) which was essentially a gravity theory. Boyd Campbell (*6*) pointed out that the hydrostatic leg and surface tension forces in the nip had been neglected but even when the theory was modified it would not explain the fact that drainage at the early rolls goes up sharply with speed, nor other facts.

Wrist saw the problem as dynamic and produced a theory which brought in centrifugal forces. This theory will not be discussed in detail as it has been recently published (*7*) but the most striking fact about it is that it predicts that the suction force at the nip of a table roll increases with the square of the speed on all but slow machines.

The expression for the suction force is

$$\frac{\rho V^2}{2} + \frac{2T}{\sigma_2} + \rho h\left(g - \frac{V^2}{r}\right)$$

where

V is the speed
ρ is the density of fluid
T is the surface tension
σ_2 is the radius of curvature of nip surface in vertical plane
h is the reduction of head of fluid on the wire on passing over a roll
r is the radius of the table roll

Of these three terms the first relates to centrifugal forces, the second to surface tension forces, and the third to hydrostatic forces above and below the wire.

The first term is very much greater than the others at high speeds and is independent of roll diameter or position on the table. The magnitude of the other terms varies from roll to roll, but for practical purposes it can be said that the suction at all table rolls depends only on speed and density.

The water extracted by a roll, however, depends upon the diameter. A small roll will suck as strongly as a large one but the latter will extract more water because of the larger nip over which the suction can operate.

An experimental check of the theory has been made. Water was run from a flow box onto a wire above a table roll and the first attempt was to insert a pitot tube into the water nip. The water curtains were too unstable. Then a very simple and effective method was found. A small perforation was made in a thin sheet of rubber giving access to a manometer. The sheet was placed on the wire over the roll and the water entrained underneath by holding up the leading edge, i.e., the edge nearest to the slice. When the perforation was at about the top dead center of the roll no pressure was registered. For about half an inch downstream there were large suction forces and upstream a small positive pressure was recorded.

Figure 8 shows the results of some measurements at different speeds and with different roll diameters, using a more refined technique. Points are not shown on the curves, for the sake of clarity, but about 20 points defined each curve and the deviation was not more than $^1/_4$ in. The increasing suction with speed

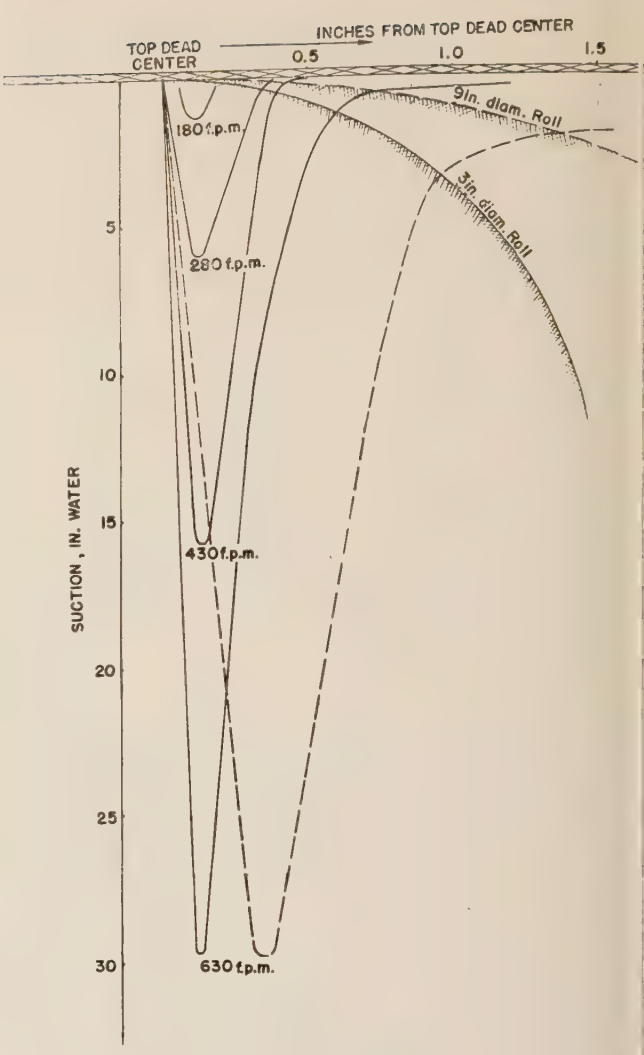


Fig. 8. Suction at table rolls

suggests a square law dependence. If the table roll is restrained so that its surface speed is less than that of the wire the suction force is reduced and if the roll is stopped, the suction reaches about half the normal value.

The length of wetted nip over which drainage takes place increases with the diameter of the roll and it depends upon the resistance of the web above the wire. At the early rolls the area of drainage may extend for an inch on the downstream side but at the last roll it is very small indeed. In the case of the newsprint machine on which the experiments were made, the suction in the first box was about the same as that developed at the last table roll, $2^1/_4$ in. of mercury, and yet the suction box removed about six times as much water. The reason is that, in the case of the roll suction operates over about $^1/_8$ in. only, after the roll.

A reasonable figure for the average length of a wetted nip would be $^1/_2$ in. Thinking of a machine going at 600 f.p.m. with 24 table rolls, each spaced 1 ft. apart, the total length of wetted nip would be 1 ft. and all the drainage would have to take place in $^1/_{10}$ sec. It is difficult to imagine $^1/_2$ in. of stock draining in this time by gravity.

The fact that on high-speed machines drainage is the result of a series of sharp impulses rather than of a continuous process should modify our ideas on stock testing and perhaps on formation.

INTERPRETATION OF THE ANALYSIS

Looking again at Table III it seems that Wrist's theory will explain the speed effect. The drainage from the breast roll and first table roll does not increase with speed. This is because here gravity drainage is predominant. The rolls are still sucking but the effect is swamped by free drainage in the area between these rolls, also this is the only part of the table where consistency is statistically significant. After this, suction drainage becomes predominant and the effect at the next few rolls is compatible with the square law. At roll 2 the magnitude of the speed-drainage effect is within experimental error of what is expected but for later groups of rolls the effect decreases and in fact it is not significant for the last group, rolls 16–21.

The explanation of this decline is not that the suction forces become weaker but that the forming web of fibers compresses. As the weight of the fibers deposited on the wire increases with successive rolls the resistance to flow increases and there is less drainage. If pulp behaved like a simple substance, sand, as a filter medium, where doubling the weight of sand in the bed would halve the flow, the effect at roll 2 should persist all down the table (the interest being in the percentage increase of flow, not the actual level). It seems that the resistance to flow of the forming web increases more rapidly than does the weight and it may be partly attributed to compression of the fibers and partly to the inhomogeneous nature of the web in which the fines are deposited later than the long fibers. The rate of increase of resistance must also be a function of speed.

A consequence of suction drainage at the early table rolls is that an increase of speed will lead to a given consistency being achieved earlier on the wire. This is in accord with practice, for one of the machine operator's aims is to get the stock further down the wire to allow the maximum time possible for formation. Grooved rolls, forming boards, etc., are an attempt to achieve this. It seems, therefore, that an increase of speed makes it easier to take out the water earlier and more difficult to take out the water over the second half of the table. The net result is that the consistency of the stock reaching the first suction box is, very roughly, independent of speed; a 10% increase of speed results in about the same increase in total table roll drainage.

The second most important factor is temperature. The effect is significant over the last half of the table but not over the first. This is to be expected on theoretical grounds. Flow through an orifice is not influenced by temperature, but Poiseuille or capillary flow does depend on temperature. The bare wire will behave as an orifice and the fully formed pad as a network of capillaries, and the dependence of drainage on temperature will change from one end of the table to the other. It is very fortunate that temperature is most effective at the drier end for it is here that speed is least effective in promoting drainage.

The measurements of stock properties showed little correlation with drainage. In the case of freeness none of the effects shown in Table III is significant, although all of them are positive. Within the range of the experiment, i.e., 43 to 59 c.s.f. in the flow box, freeness has no strong influence and is certainly less important than speed and temperature. The stock properties measured do not seem to be important as far as drainage is concerned but that is not the same as saying that drainage is unaffected by the nature of the stock. Rather does it point to the wrong properties being measured. The freeness tester has been criticized on many counts, it is influenced by "fines" more than is the paper machine, etc. Another criticism to be made as a result of this work is that instead of a stock test carried out under the gentle and continuous conditions of gravity flow an alternative is required in which drainage takes place in a series of short, sharp jerks, the magnitude of which is adjusted to the speed of the paper machine. The conditions of filtration are totally different in a freeness tester from those on a high-speed paper machine.

In Table III another factor was eliminated which has not been mentioned, a time factor to allow for the aging of the wire. Actually, the regression analysis as originally worked out showed a small but significant freeness effect at the very early rolls, but it was later noticed that some of the experimental measurements showed a steady trend with time. When the analysis was corrected for the time factor the freeness effect disappeared.

SUBSEQUENT WORK

The conclusions reached are strictly only valid for the one newsprint machine on which the experiments were done and for the range covered by the readings, which was quite small. Another similar experiment has been done on the same machine but in this case, instead of the machine running normally, it was constrained to run at different combinations of the factors. For instance the speed was either 600, 640, or 680 f.p.m., the temperature 35 or 45°C., etc. This factorial experiment was analyzed by a more powerful method, the analysis of variance, which led to more information about the interdependence of factors. Also, the range of the experiment was greater than the one discussed.

In an attempt to generalize the problem and get away from this one particular machine, a study is being made of the drainage resistance as derived from the ratio of the flow and suction at a roll and the way this depends upon stock properties. Sufficient background information has been obtained from the paper machine for work to be carried out in the laboratory on drainage resistance and experimental checks on the suction theory of drainage.

It is hoped to be able to publish this work at a later date.

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Influence of Differential Speeds Between Stock and Wire on Sheet Properties

O. ANDERSSON and J. BERGSTRÖM

This paper deals with the influence of the speed difference between the stock and the wire at the moment the stock is deposited on the wire as well as lateral conditions governing the way in which this deposition is made and the water is handled at this procedure. The experiments were performed on the experimental paper machine at the Swedish Forest Products Research Laboratory. In this investigation, which covers the range of 100 to 200 in. per min., the results indicate that the optimum speed difference increases almost proportionally with the speed of the wire; at wire speeds from 150 to 200 in. per min. being within the region 10 to 20 in. per min. for this particular machine. The best isotropy and the closest structure of the sheet are obtained if the dewatering is delayed and the formation is allowed to occur under moderate drainage.

PAPERMAKERS have claimed that the paper is made at the point where the stock meets the wire. Others have also been claimed that the most important part of the wire is the first foot after the slice. This is certainly true to a considerable extent as far as the properties of the paper web are concerned, as optimum conditions that were not reached in deposition of the fibers on the wire can never be reached by efforts in the later part of the paper machine.

The present study deals with the influence of the speed difference between the stock and wire at the moment the stock is deposited on the wire as well as lateral conditions governing the way in which this deposition is made and the water is handled at this procedure.

EXPERIMENTAL

The experiments were carried out on the experimental paper machine at the Stockholm laboratory. The design of this machine is published elsewhere (*1*), but for the understanding of the experiments to be described a flow sheet of the wet end as it was run during the experiments is shown in Fig. 1.

The pulp, which was prepared beforehand, is stored in a machine chest, from which it is pumped to the headbox, and the sheet goes from the couch directly down to the couch pit where it is mixed with white water and pumped back to the machine chest. An outline of the wire section is shown in Fig. 2. The headbox has a standard Voith outlet and immediately after the breast role there is a forming box with four section legs. The details of the outlet are shown in Fig. 3. Under the jet there is an adjustable rubber apron, and in some of the experiments the position of the apron was varied, ending at positions 1, 2, and 3.

Samples for measurements of physical properties were taken out by leading the web to the first press and cutting the web between the couch and first press. The paper scraped off the press roll during sampling was transferred manually to the couch pit.

These samples were pressed between blotters and dried between polished plates. After drying and conditioning to 65% R.H. they were used to measure breaking length, rupture elongation, bursting strength, tearing strength, air resistance, fiber orientation, and formation number. The formation number was measured optically as the ratio between the root mean square of the alternating and the steady components of light transmitted through the sheet. On some occasions stock was taken from the headbox to prepare check sheets on a sheet machine.

On the paper machine were measured: (1) drainage from the wire, the free draining part of the wire being divided into five sections; (2) drainage from the flat boxes; (3) air flow through the flat boxes, the vacuum of the boxes being kept constant; and (4) air flow through the couch.

During each experiment the wire speed and the position of the fan pump valve were kept constant, and the speed of the stock was varied by adjusting the slice opening to give the linear speed required; measurements were not made until after each adjustment. The level in the headbox was constant. In some experiments the headbox was run with an air cushion.

MECHANISM OF DEPOSITION ON THE WIRE

The ideal way of making a sheet on a paper machine would be a dilute suspension of fibers in uniform translatory motion being deposited on the wire without any relative velocity components in the horizontal plane, this procedure followed by drainage quick enough to prevent the fibers from sedimenting and flocculating. For the first approximation this is achieved on the paper machine by running the wire at exactly the same speed as the jet. This, however, requires an even velocity distribution of the stock, as shown in Fig. 4, upper sketch. In practice, there is a certain velocity profile, but even if the velocity profile of a fiber suspension may be square across the greater part of the vertical cross section, this cannot be true close to the boundaries. The middle picture of Fig. 4 shows what could happen in a practical case when the stock hits the wire, if the wire has the same speed as the bottom layer of the stock. The bottom figure shows a possible development of the velocity profile in the presence of an apron.

By the use of a pitot arrangement the velocity profile shown in Fig. 5 was obtained from the experimental paper machine. Unfortunately the pitot method is not sufficiently accurate to obtain the detailed profile,

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but the presence of air at the upper boundary and an apron at the lower boundary could easily explain this type of velocity profile. Knowledge of the behavior of this flow when it reaches the wire requires a rigorous theoretical-hydrodynamical treatment which lies far beyond the scope of this study.

The speed of the lowest layer of the stock when it leaves the apron is probably zero, although it might rise to the speed of the square part of the profile quite quickly when proceeding to higher layers. There is no reason why the best sheet properties should be obtained when the wire speed is equal to that of the square part of the profile, the ideal conditions outlined above could certainly never be approached as long as there is a velocity distribution like the present one. There is reason to believe that the wire speed should match the over-all speed of the stock approximately; when the stock hits the wire there is probably created a stirring action which should be controlled in such a way that it does not obstruct the desired fiber arrangement already achieved but does disturb the alignment along the streamlines of the stock flow.

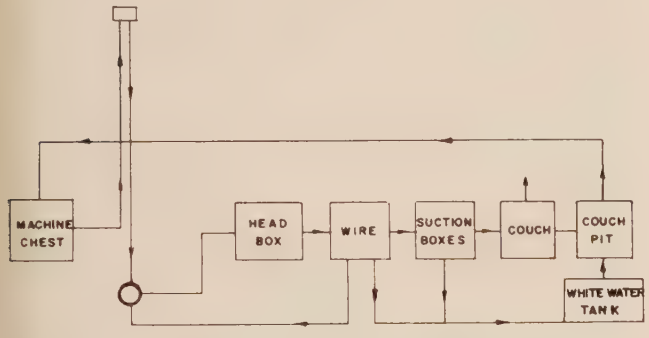

Fig. 1. Flow diagram of the wire section of the experimental paper machine

This optimum speed difference is probably quite critical and depends on many factors such as concentration of the suspension, fiber length distribution, headbox design, slice design, apron arrangement, drainage characteristics of the point of deposition, etc. The optimum speed difference is probably also a function of the absolute speed of the stock or wire, although there is no *a priori* reason to believe that it should be proportional to the absolute speed, even if experience sometimes indicates this.

RESULTS

In a preliminary run the paper web was taken from the couch through the press and drier sections. Samples were taken at different positions in the paper machine for tensile testing, and the web was marked at the same position for measurement of shrinkage between different sections of the machine. The pulp was a standard Swedish sulphite pulp beaten to 30° S.-R. The wire was run at a speed of 100 m. per min. and the speed of the stock was varied between 80 and 120 m. per min., these velocities being calculated from the velocity head in the headbox by application of a known orifice coefficient. To what extent these velocities describe the over-all speed of the jet is not known. However, measurements made with a pitot arrangement

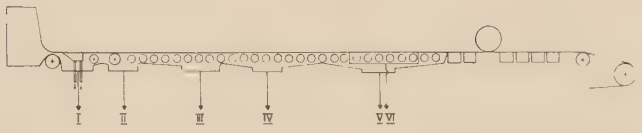

Fig. 2. Outline of the wire section of the experimental paper machine

later on show the values in this particular experiment to agree with the surface speed close to the jet within 5%.

The samples show the lowest tensile strength and the highest rupture elongation at the couch; from the couch to the reel the tensile strength increases and the elongation decreases. The strength anisotropy is lowest at the couch and increases toward the reel just as the elongation anisotropy. Both the strength and the elongation show minimum anisotropy at a speed difference of −10 m. per min. the negative sign indicating higher wire speed. The strength anisotropy is 1.5 and the elongation anisotropy less than 1 at this speed. The impact strength also shows isotropy at this speed difference. The machine direction shrinkage shows maximum at this speed difference; at the same time as the cross-direction shrinkage shows a broad minimum.

From these experiments we have learned that desired properties of the sheet can be approached by proper setting at the wet end, but they can quite readily be destroyed in the press and drier sections. On the other hand, faults introduced during the sheet formation can scarcely be remedied in the later parts of the paper machine.

After this preliminary experiment attention was focused entirely on the wire section, the stock being a standard kraft pulp, beaten to 30° S.-R. Two duplicate runs were made at a wire speed of 150 m. per min. to obtain an idea of the reproducibility of the experiments. A third run was made under the same conditions but with four suction legs working on the forming box to obtain maximum dewatering at the point of deposition. A fourth run was made at a wire speed of 200 m. per min. for a study of the influence of the absolute speed; during this run full suction was applied in the forming box.

Of the sixteen quantities measured during each run some did not show an appreciable variation with the speed of the stock, although some showed a pronounced tendency toward maximum or minimum at a certain stock speed. At a given stock speed these maxima and minima all occur in the same region of stock speed.

Figure 6 shows the variation of the air flow through

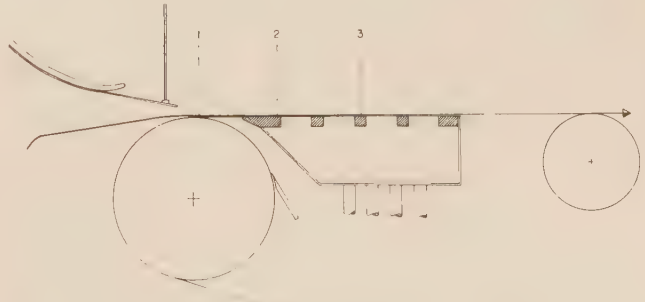

Fig. 3. Possible development of velocity profiles adjacent to the outlet

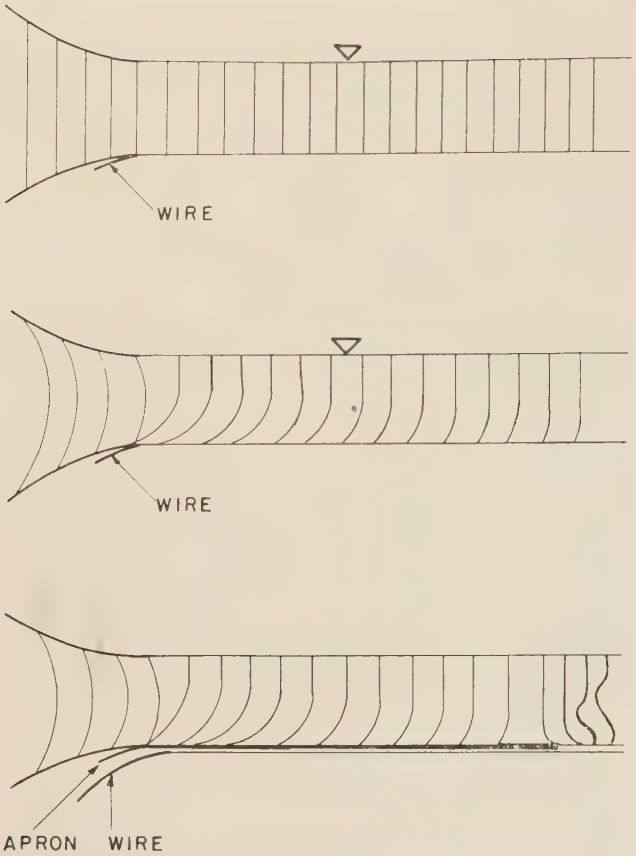

Fig. 4. Measured velocity profile at the edge of the apron on the experimental paper machine

the fifth suction box. The first number attached to each curve gives the wire speed, and the second number the number of suction legs in action. The absolute values of the air flow in the four different runs should not be compared as there might be minor variations in beating and basis weight between the runs. It can be seen that the two curves from the duplicate runs a 150 m. per min. have practically the same shape. There is a pronounced decrease in air flow toward the region 130 to 140 m. per min., indicating that there is a maximum in the density of the sheet in that region. Visual inspection of the sheets shows a definite maximum in the evenness of the sheet in the same region; at the highest and lowest stock velocities the sheet is quite wild and shows the presence of big flocs.

The curve corresponding to a run at 150 m. per min. and application of full dewatering of the forming box (150.4) shows a similar tendency, although it is by no means pronounced, and the same is true for the 200-m. run where full suction was also applied. In this case, the minimum occurs around 180 m. per min.

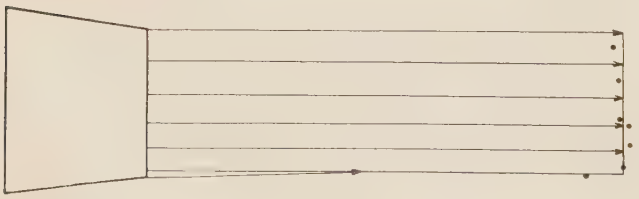

Fig. 5. Design of the outlet and forming box of the experimental paper machine, positions of the edge of the apron during the experiments indicated by Figs. 1, 2, and 3

The breaking length in the machine direction is shown in Fig. 7. There are some irregularities, but there is a general tendency toward a minimum between 130 and 140 m. per min. at the lower speed, the minimum being equally pronounced whether there is a full dewatering or partly prohibited dewatering. The curve for 200 m. per min. does not show a minimum. Whether this is due to the sheet formation at this higher speed being of different nature or to handling of the wet sample being more difficult cannot be explained without repeated experiments.

The ratio between machine and cross-direction strength is shown in Fig. 8. All runs show a minimum: for the 150-m. per min. run in the region 130 to 140 m. per min. and for the 200-m. per min. run between 180 and 190 m. per min. Again, there is no appreciable difference due to difference in intensity of dewatering. It may be noted that the lowest value observed here is very close to 1.0, i.e., the same strength in both directions. In all these cases the ratio between rupture

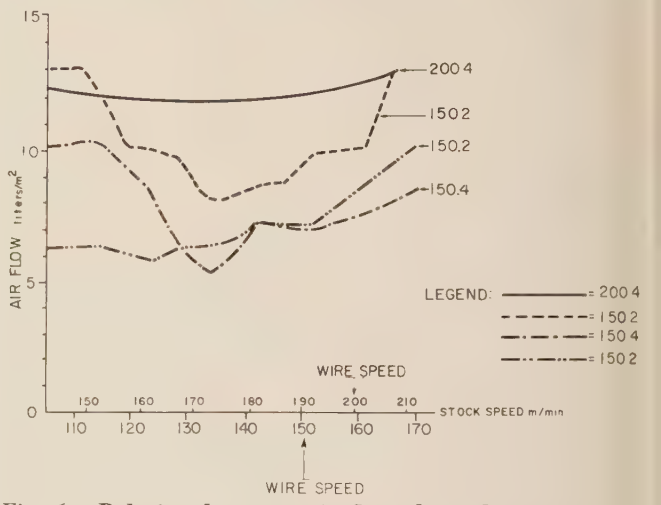

Fig. 6. Relation between air flow through flat box and stock speed, numbers on curves indicating speed of wire and number of suction legs of the forming box

elongation in the machine and cross directions is very close to 1 at the minimum point.

In one of these runs colored fibers were inserted to make possible a determination of the fiber orientation. The orientation factor was calculated from the formula

$$\frac{45 - v}{45}$$

where v is the average angle between the fibers and the machine direction. This factor is zero if there is no preferred orientation and 1 if all fibers are aligned in the machine direction. The variation of fiber orientation is shown in Fig. 9. It appears that the orientation factor stays between 0.1 and 0.2 for most of the speed differences, but around 135 m. per min. it drops down to 0.02. The tendency toward isotropy around this speed is evidently mainly due to a randomization of the fiber direction at the outlet.

Figure 10 shows the variation of the initial slope of the stress-strain curve in the machine direction. These curves follow the tensile strength curves quite closely, indicating that the properties measured are primarily determined by the fiber arrangement. The conclusion

from these runs is that there is an optimum in sheet formation in a certain region of stock speeds, i.e., where the wire is running between 10 and 20 m. per min. faster than the stock, in the wire speed region investigated. The flow speeds given on the diagrams are calculated from the level difference between the headbox and the wire, so it should match the speed on the surface of the suspensions on the wire. It checks with pitot measurements a few millimeters under this surface.

This optimum is characterized by a minimum of air flow through the fifth flat box, a minimum in fiber orientation, a minimum in strength anisotropy, and a minimum of anisotropy of elastic properties. A stronger dewatering at the point of deposition seems to decrease the strength of these optima, making the sheet less anisotropic at the optimum point. This may be due either to the direct action of the draining water or to the fact that the sheet becomes consolidated too fast and is not influenced by the action of the forces rearranging the fibers.

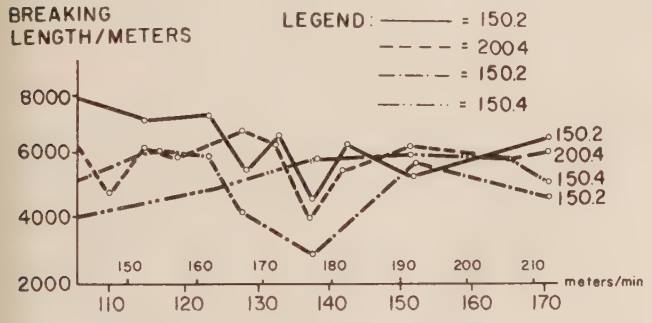

Fig. 7. Relation between breaking length and stock speed

For a closer investigation of this question a series of runs were made in which the number of open suction pipes of the forming box was varied and the edge of the apron was moved to three different positions: (1) to a point 2 in. from the lower lip, (2) to the first slit, and (3) to the third slit of the forming box. These positions will be referred to as positions 1, 2, and 3 (Fig. 3). At different settings of these variables the wire was run at 100 m. per min. and the stock from 71 to 113 m. per min.

The intention of changing the edge of the apron to different positions was to vary the period of flow without drainage between the slice and the wire. To avoid confusion of the mass of data that was obtained from these runs different properties have been listed against one variable at a time, each value being an average over the other variables.

Figure 11 shows the variation of the strength ratio with stock speed, position of the apron, and the number of suction legs. The minimum of strength orientation now occurs in the region 89 to 95 m. per min., i.e., a situation similar to the one shown before. After these runs it turned out that during the run where the apron was in position 2 the stock to the machine had a lower degree of beating than in the others. Therefore, this run has to be omitted in comparing the results at different apron positions. Figure 11 shows a tendency to lower anisotropy toward position 3 supporting

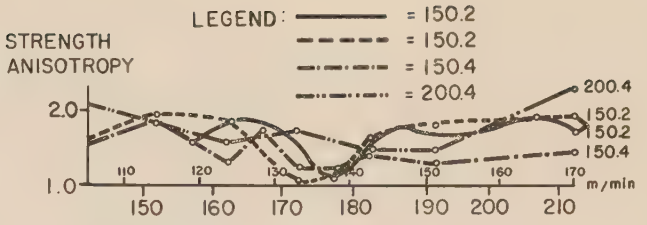

Fig. 8. Relation between strength anisotropy and stock speed

the assumption that an adjustment of the fiber arrangement is obtained if the stock is allowed to flow initially without dewatering. In this particular case this period is of the order of $^1/_2$ sec. As far as rate of dewatering is concerned the bottom diagram confirms the earlier findings, that earlier dewatering produces a higher orientation, this probably being due mainly to increased vertical flow components as the total variation due to this factor is larger than the variations due to difference in position of dewatering.

Among other properties measured the flocculation might be of some interest. For a sheet completely free from flocs this should be equal to zero. Figure 12 shows a decrease in formation number with increasing number of suction legs and an increasing number with increase in length of apron.

This may seem somewhat contradictory to the result earlier obtained, as the most even and homogeneous sheet was obtained if a long period of dewatering was allowed and dewatering during sheet formation was kept small. However, a low formation number does not necessarily mean a strong and unorientated sheet. At quick dewatering immediately after the outlet, the fibers are probably frozen in an aligned and loose structure. It could thus be considered uneven on a very small scale, such a small scale that it is beyond the resolution of the human mind and beyond the frequency limit of the formation tester. Such a sheet may have quite low strength and high orientation; the properties are entirely due to the construction of the headbox and the outlet, although the speed difference between stock and wire has a minor influence.

SUMMARY AND DISCUSSION

A sheet with a reasonable formation and with very little anisotropy in fiber orientation and mechanical properties can be obtained at the couch by proper adjustment of the outlet. These properties are, however, easily obstructed during pressing and drying. The setting of the outlet parameters depends upon the velocity distribution and properties of the suspension at the outlet as well as the absolute speed. In the present investigation, which covers the range 100 to 200 m. per min., the results indicate that the optimum speed difference increases almost proportionally with the

Fig. 9. Relation between fiber orientation and stock speed

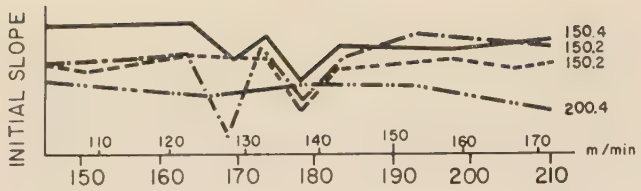

Fig. 10. Relation between initial slope of stress-strain curve in machine direction and stock speed

speed of the wire; at wire speeds from 150 to 200 m. per min. being within the region 10 to 20 m. per min.

The best isotropy and the closest structure of the sheet are obtained if the dewatering is delayed and the formation is allowed to occur under moderate drainage. By earlier and more intense drainage the sheet becomes more oriented but has a better visual formation. Change of drainage rate and draining position does not change the optimum speed difference.

All the data obtained in these experiments agree on one point. The properties of the sheet made on the paper machine wire vary with the speed difference between the stock and wire as well as the intensity and method of application of drainage immediately after the deposition of the stock on the wire. Generally, these variations appear as maxima or minima, and these maxima and minima can be traced down to a common source, the arrangement of the fibers in the sheet. There are however still many question marks, especially involving the relation between the hydrodynamical behavior of the stock on the wire and the independent variables, the wire speed, and the distribution of stock speeds.

In the present study it has been possible to treat this and related effects superficially. However, it does not

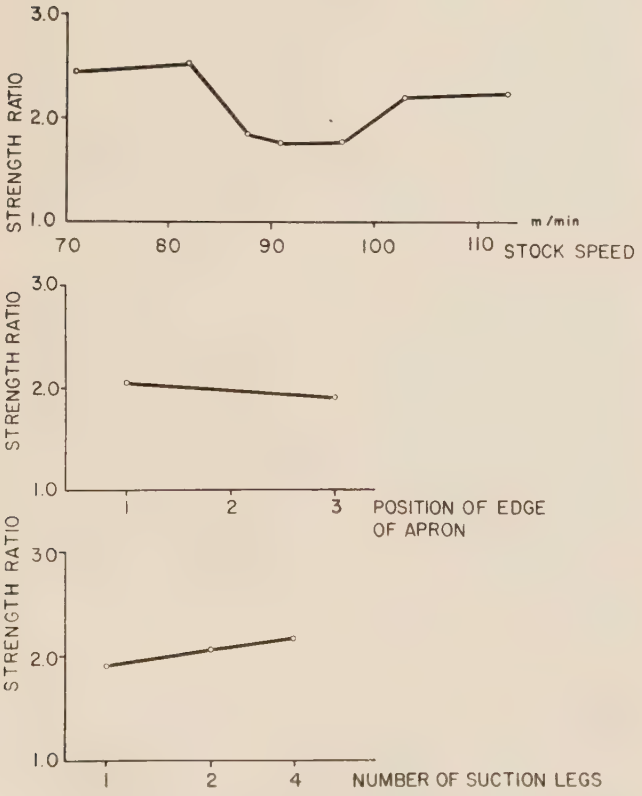

Fig. 11. Relation between strength ratio and independent variables studied

answer the question why the optimum wire speed should be higher than any speed in the velocity profile of the stock.

A possible answer to this question is the following. When the upper surface of the jet leaves the edge of the outlet and encounters air, there is a drastic decrease in boundary friction. In fact, the air is dragged with the stock and offers very little resistance against the flow at the boundary. Therefore, as confirmed by experiment, the velocity at the boundary quickly catches up with the velocity in the middle of the cross section, and a practically square profile develops throughout the cross section, except at the lower boundary where there is still friction against the apron.

When the apron is substituted by the wire, a similar thing occurs, especially if the wire is running at the same speed as the one in the square part of the profile. The jet reacts as if there were no friction and a more or less square velocity profile develops. This means

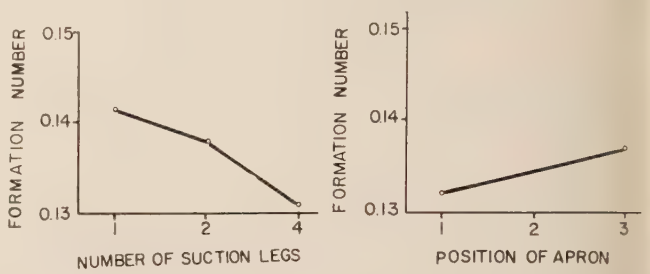

Fig. 12. Relation between formation number and independent variables studied

no, or very little stirring action and therefore no fiber rearrangement. It is assumed that the fibers had a tendency to align themselves along the streamlines in the headbox and outlet.

By this line of reasoning there must be a wire speed higher than the highest stock speed to create an effective stirring action and promote a rearrangement of the fibers. If this wire speed is too high the stirring action might be too violent and the wire might have a combing effect which aligns the fibers again after the alignment produced in the outlet has been destroyed.

Another question: how does the movement of the fibers respond to different characteristic types of velocity profiles which could be encountered on a fourdrinier wire? Is there an optimium combination of variables where a maximum fiber alignment could be reached? Is there a general relation between the wire speed and a characteristic stock speed parameter, which gives the optimum properties of the sheet?

To obtain an answer to this question it is necessary to go back from the paper machine and do a fundamental study of the flow of suspensions between moving boundaries. We also require more knowledge of movements of fibers in shear fields than the present status of science can offer us.

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These experiments were carried out on the experimental paper machine in the Central Laboratory of the Swedish Paper Industry. The authors wish to express their gratitude to Otto Brauns, the head of the laboratory, and to Börje Steenberg, head of the Paper Technology Dept., Swedish Forest Products Research Laboratory.

Drainage Effects and Two-Sidedness

G. F. UNDERHAY

Differences in the composition and general structure of the top side and the wire side of uncoated mass produced general printing and newsprint papers are discussed in relation to fourdrinier drainage conditions. Investigations have been carried out on fairly fast machines using newsprint and similar furnishes, and the results of paper analyses, as revealed particularly in loaded papers, show that the amount of very fine material carried in the top side is likely to be at least twice the amount in the under side. After many failures to reproduce this composition two-sided effect with normal sheetmaking equipment in the laboratory, the result was finally achieved by introducing a rapid relative vertical oscillating movement between the wire and the draining water beneath during sheet formation. This disturbs and washes the under side of the immature sheet, and fine material is loosened and removed preferentially from the under side in this way. It seems that medium and high-speed table roll action is similar in that water is squeezed into the wire side at the nip and then withdrawn on the suction side of the roll. Some support for this explanation has been obtained by producing non-two-sided paper on a very slow machine. Although sheet quality is affected remarkably little, solely because of composition two-sidedness, it is suggested that the subject deserves more attention than it has had in the past, particularly since the high wire losses resulting from this action have an important influence on breast box stock properties.

When using paper stocks of mixed fiber length and composition, such as those required for newsprint and similar mass produced qualities of printing paper, drainage conditions on fourdrinier machines have a marked influence on the structure and composition of the paper made. The normal result is that the top surface of the paper, due to the presence of a greater proportion of short and fine material, has a closer and finer structure than the under surface where the longer fibers of the furnish predominate and the texture, in consequence, tends to be more open. The subject is of interest not only from the point of view of paper quality, but also because of the closely allied effects on the properties of the breast box stock which, with closed backwater systems, result in an accumulation of a much greater proportion of fine material in breast box stock than is present in the original stock. The drainage conditions which arise when making newsprint and similar papers at all but very low speeds are responsible for this, and the amount and nature of the suspended material present in the resulting wire pit water have an important controlling influence on breast box stock properties.

It is proposed to discuss these interrelated effects of drainage conditions, breast box stock, and sheet structure as they form an important branch of wet end studies. Much of the work to be described was, in fact, carried out many years ago but as this conference has been planned for exchanging knowledge and theories about fourdrinier wet end operation, it has seemed an appropriate opportunity to draw the results together for publication. In doing so, the author would like to acknowledge the help and advice of two of his colleagues: S. V. Sergeant, who has carried out some of the recent tests as well as some earlier ones, and J. F. Smith, a former associate who was concerned with the early experimental work some years ago.

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TYPES OF TWO-SIDEDNESS

In order to be clear about the scope of these investigations, it will perhaps be useful to review the main ways in which differences in the appearance and properties of the two sides of paper can arise.

There are, firstly, differences which are due almost entirely to the effects of contact with machine clothing and with pressing, drying, and finishing equipment. Thus, impressions on one side or the other may carry the general pattern of felts or wires, and in the case of the wire there may also be some molding of the sheet round the knuckles during the drainage process. During drying there is the extreme example in which one side, by design and at the expense of the other, is highly smoothed and polished by contact with an MG surface; and, in finishing, there are the different effects produced by metal and paper rolls and the necessity, therefore, for most purposes, of endeavoring to balance these up as evenly as possible.

Secondly, there is the difference in the over-all flatness of the two sides of paper which results, particularly in the case of heavier papers, from the fact that one side is formed in contact with the wire while the other side is free as drainage proceeds to form hills and valleys according to the degree of coagulation of the stock and the mobility of the suspension on the wire. One of the reasons for using a dandy roll is, of course, to mitigate this effect. The greater the basis weight of the paper being made the greater are the chances of the wire side being generally flat (although, of course, it may be wire marked), while the top side will tend to be undulating and irregular. However, at the substance at which newsprint and similar paper is made, which is our primary concern here, it is doubtful whether any noticeable effect on two-sidedness arises from this cause.

Lastly, there is the kind of two-sidedness and its causes and effects at the wet end of the machine which form the main thesis of this contribution. This two-sidedness is characterized particularly by the marked differences that occur in the composition of the two sides of paper. In addition to being responsible for some differences in both texture and color, the drainage mechanisms involved, which give rise to the composition differences of the two sides, also have an important effect on the properties of the breast box stock, and it is proposed to consider all these aspects of the problem in the light of investigations that have been carried out.

Table I. Distribution of the Ash Content of Paper as Shown in Three Typical Samples

	1	2	3
Basis weight, g./sq. m.	61.9	62.8	62.5
Basis weight g./sq. m. (24 × 36, −500)	38.0	38.6	38.4
Ash content of laminations, %			
Top	12.3	11.8	9.9
Top middle	12.7	11.7	9.5
Wire middle	9.0	8.4	6.9
Wire	5.2	4.7	3.6
Basis weight of laminations, g./sq. m.			
Top	19.1	19.5	19.9
Top middle	13.9	11.6	13.2
Wire middle	11.1	12.3	12.4
Wire	17.8	19.2	17.0
Total ash content, % (calculated from laminations)	9.7	8.9	7.5
Total ash content, % (determined on whole sheet)	10.2	9.4	7.5

Although most of the conditions associated with the production of two-sidedness are well known to papermakers, the extent of the nonuniform distribution of the furnish in the sheet is not always fully appreciated, and it is this aspect of two-sidedness together with the closely allied subjects of the drainage conditions and the effect of these on the composition of breast box stock which are now to be considered.

CONDITIONS TYPICAL OF COMPOSITION TWO-SIDEDNESS

Starting firstly with the paper itself, some typical results are given below for fairly heavily loaded printing papers made from newsprint quality groundwood and sulphite pulp. The paper was examined by splitting* it into four laminations and determining the ash content of each layer.

The results show that the ash content at the top of the sheet, in all cases, is more than twice the ash content on the wire side; these examples are typical of the differences that exist in the composition of paper of this type made under present-day papermaking conditions. The paper was, in fact, made on a modern moderately fast machine operating in the range 800 to 1000 f.p.m. Although the sheet, which in this case was supercalendered, can readily be seen to have a normal two-sided appearance, it is worthy of note that no significant differences in the properties of the two sides were revealed either by the Ingersoll glarimeter or by the Bekk smoothness tester, and any differences that there may be in printability, due solely to composition differences, seem to be very small.

It will be recognized, of course, that an essential factor giving rise to the production of paper of the kind shown in Table I is the furnish. Stock free from loading and composed of fibers substantially uniform in size will give paper of uniform composition throughout whatever the drainage conditions. But groundwood, the main constituent of these samples, is notoriously heterogeneous in nature ranging as it does from fine fiber fragments that can pass easily through a 200-mesh sieve, to good long fibers that can be retained on 24 and coarser mesh screens.

When loading material is used in the furnish, as in the cases given in Table I, ash tests provide a convenient way of indicating the composition differences that occur through a sheet, the loading being associated mostly with the finest constituents of the furnish. Independent qualitative tests have, however, been made on the fibrous furnish of the top and wire side of paper of this kind and these have shown that there is an excess of groundwood in the top layers as would be expected, and an excess of sulphite on the wire side.

Having then discussed the kind of composition differences that exist in fairly high-speed groundwood printing papers made on fourdrinier machines, the stock conditions that are a result of the mechanisms which produce composition two-sidedness will now be considered.

It is, of course, common knowledge that the breast box stock used for making newsprint is very different in composition from the machine chest stock from which it is derived. Examples of the composition of these two stocks and of the corresponding wire pit water are given in Table II.

The fact that the finished paper contained an ash content of only 7.5% compared with an ash content of 20.6% in the total solids in the breast box stock, is enough in itself to show that losses through the wire are heavy and that this is an important cause of the composition differences between machine chest stock and breast box stock. The wire pit water, too, has the same story to tell and its total consistency compared with that of the breast box indicated, in fact, that the total losses through the wire during sheet-making are probably somewhere between 35 and 40% of the stock fed on to the wire. Some of these losses are due to very fine suspended material being carried away with the drainage water from all parts of the sheet during its formation on the wire. Arguments will be put forward, however, which, it is contended, show that substantial losses are also due to the removal of fines preferentially from the under side of the sheet. These losses arise as a result of disturbances and washing of the under side during its passage over the table rolls.

MACHINE LOSSES THROUGH THE WIRE COMPARED WITH LABORATORY LOSSES

Running at speeds in the neighborhood of 1000 f.p.m. on newsprint and similar furnishes, and at newsprint and printing paper substances, it can be shown that total losses through the wire are in the region of 35 to

Table II

	Machine chest stock	*Breast box stock*	*Wire pit water*	*Finished paper*
Total consistency, %	2.80	0.75	0.28	...
Fiber consistency, %	2.45	0.58	0.17	...
Ash content of solids, %	11.1	20.6	36.4	7.5
Freeness, ml., Canadian	173	64	...	...
Drainage time at 60 g./sq. m., sec.	13.9	29.3	...	...

* There are several ways in which variations in the composition of the paper through its thickness can be examined. The method used here, which is very serviceable after some practice, involves sticking strong gummed paper on each side of the sample. After drying, the two sheets of gummed paper are pulled apart and roughly half the paper will be found attached to the face of one gummed sheet and the other half of the paper will be on the other. These two laminations can be removed from the gummed paper by soaking in water, care being taken to see that fine material, particularly loading, is not lost in the process. Provided the original paper was not too thin, these two split sheets can be taken and split once more into laminations in the same way as the original sheet. The four laminations finally obtained are weighed and the ash content or fiber composition determined.

40% or higher. These are quite normal figures, and the losses tend to increase as machine speeds increase. It is interesting, therefore, to compare this behavior with the behavior of the same kind of stock drained in the laboratory through stationary wires under various conditions.

Breast box stock was sampled a few weeks ago on a machine making a quality of paper somewhat better than newsprint from a selected newsprint furnish, and running at 1150 f.p.m. on a substance of 51 grams per sq. m. (31.3 lb. 24 × 36—500). The breast box stock had a total consistency of 0.71%, and the ash content of the solids in the stock was 11.5%. This stock was used for making laboratory sheets of 60 grams per sq. m. (36.8 lb. 24 × 36—500) on the standardized British sheet-making equipment, with all the operations carried out in the standard way. (Second Report of the Pulp Evaluation Committee, Proc. Tech. Sect. Paper-makers' Assoc., 16: 303 (1936)). The results showed that under these circumstances the total losses through the sheet machine wire averaged around 15%. They are thus much below the losses obtained from the same stock under commercial operating conditions (in this case about 35%) and they show, in fact, the usual relationship that the laboratory losses under static drainage conditions are rather less than half the losses on the commercial machine. Furthermore, sheets made in this way in the laboratory on the sheet machine using the standard suction do not exhibit two-sidedness. Trials have been made at various dilutions ranging from the standard (0.017%) to that used in the mill (usually about 0.75%), and also using various furnishes, including particularly breast box stock, but on no occasion has an under side been produced in the laboratory under static draining conditions comparable with that of mill-made paper. On the contrary, at the higher dilutions, the appearance of the under side may be more compact and close textured than the top side.† Losses through the wire with newsprint types of furnish can be increased up to about 25% in the laboratory by using a 60-mesh wire in place of the standard 150-mesh wire, but keeping the rest of the conditions and procedure standard. On the other hand, losses can be decreased down to about 10% or less using the standard 150 wire but pouring the stock directly onto the wire under nonstandard conditions in which the drain cock is open and there is, therefore, no water above or below the wire at the time that the stock is poured on. In all these cases, however, there is no evidence of composition two-sidedness of the kind that occurs on paper machines.

ATTEMPTS TO REPRODUCE IN THE LABORATORY TWO-SIDED PAPER SIMILAR TO THAT MADE ON COMMERCIAL MACHINES

In trying to determine the essential mechanism that gives rise to composition two-sidedness on paper machines, it was decided first to confirm that after couching and before drying the paper is two-sided. Samples have, therefore, been taken for examination after both the first and second presses. They were carefully smoothed out and gently pressed by hand onto stainless steel plates, first with the wire side against the plate, and second with the top side against the plate. The samples were then pressed and dried normally in the standard apparatus. On inspecting the sheets and comparing them with the same paper finished on the commercial machine, there was no doubt that two-sidedness was fully developed at that stage.

One would like similarly to be able to take samples of the immature sheet before it passes over the suction boxes and the suction couch, to check whether or not the fully or partially developed symptoms of two-sidedness are present before the suction boxes are reached. Being unable to do this, however, experiments were designed to determine, in the laboratory, the effect of applying suction so that some indication might be obtained as to whether the operation of the suction boxes and the suction couch contribute materially to the production of composition two-sidedness. A large oil drum, capable of being evacuated to a vacuum of 25 in. or more by means of a laboratory filter pump, was connected to the drainage system of a laboratory sheet machine, or alternatively to the laboratory consistency apparatus (an unbacked 5-in. diameter wire supported on a brass ring over a conical receiver, and fitted with a short $3^1/_2$-in. detachable sheetforming cylinder (*see* Second Report of the Pulp Evaluation Committee, Tech. Sect. Papermakers' Assoc., 136 (1936)) in such a way that it could be used either to augment the suction due to the water in the drainage system, or the vacuum could be applied after normal drainage had been completed. Furthermore, a shallow circular trough was constructed so that by transferring the sheet machine gridplate to it with a wet normally drained sheet on it, and then applying vacuum, a more violent and sudden effect could be obtained with this much smaller capacity system than was possible in the sheet machine itself, or in the consistency apparatus.

The full results of a series of tests with details of the experimental technique, using in one case the original Clark $5^1/_4$-in. forerunner of the standard British cylindrical sheet machine (J. d'A. Clark, *Proc. Tech. Sect. Papermakers's Assoc.* 7: 247 (1927)) and, in the other, the consistency apparatus, are given in Table III. Three sheets were made under each set of conditions, one being used to determine the ash content, and the other two were pressed and dried in contact with stainless steel plates, one having the wire side against the plate and the other the top side. Top and wire sides could, therefore, be compared under similar conditions and it is satisfactory that the finish produced approximated that of supercalendered newsprint.

As will be seen from the table, none of the sheets showed any trace of two-sidedness. Although the total losses were fairly high, ranging between 12 and 22%, they were not as high as the 35 to 40% or more found on commercial machines. The results do indicate, however, that suction boxes and suction couches are not a primary cause of the composition two-sidedness we are seeking to explain.

Other conclusions to be drawn from Table III are that a 4 to 1 dilution of the breast box stock for sheet-making has little effect on the losses which occur under these static wire conditions; that the consistency

† To examine the appearance of the top and wire sides of paper made on the standard sheet machine, it is necessary to make at least two sheets under each condition; the top side of one and the under side of the other should then be dried in contact with a stainless steel plate. After drying, the glazed sides of the sheets can be compared visually and, with experience, it is readily possible to detect composition two-sidedness.

Table III. The Effect of Suction

	5¼-in. circular sheet machine with short cylinder				Consistency apparatus			
	Water up to wire level		No water beneath wire		Water up to wire level		No water beneath wire	
	Simultaneous drainage and extra suction 1	Normal drainage followed by sudden suction (in shallow trough) 2	Simultaneous drainage and extra suction 3	Normal drainage followed by sudden suction (in shallow trough) 4	Simultaneous drainage and extra suction 1	Normal drainage followed by sudden suction (in shallow trough) 2	Simultaneous drainage and extra suction 3	Normal drainage followed by sudden suction (in shallow trough) 4
Breast Box Stock; Undiluted (100 Ml.); Total Consistency 0.879%, Ash 15.8%								
Weight of sheet (moisture-free)	0.701	0.710	0.740	0.755	0.702	0.710	0.763	0.772
Ash weight (moisture-free)	0.075 = 10.6%	0.078 = 11.1%	0.084 = 12.0%	0.089 = 12.7%	0.077 = 11.0%	0.084 = 11.8%	0.093 = 12.2%	0.099 = 12.9%
Total loss, %	20.3	19.3	15.9	14.2	20.1	19.3	13.3	12.2
Fiber loss, %	14.6	14.6	11.4	10.0	15.5	15.4	9.5	9.0
Ash loss, %	46.0	44.0	39.6	36.0	44.6	39.6	33.2	28.8
Top side	Smooth throughout							
Under side	Smooth throughout							
Breast Box Stock; Diluted (100 Ml. in 500 Ml.)								
Weight of sheet (moisture-free)	0.690	0.692	0.741	0.773	0.889[a]	0.891[a]	0.949[a]	0.819[a]
Ash weight (moisture-free)	0.074 = 10.7%	0.076 = 11.0%	0.089 = 12.0%	0.094 = 13.5%	0.116 = 13.0%	0.118 = 13.2%	0.129 = 13.6%	0.127 = 13.8%
Total loss, %	21.5	21.3	15.8	12.0	19.2	19.0	13.7	16.5
Fiber loss, %	16.8	16.8	11.9	9.5	16.4	16.4	11.3	14.5
Ash loss, %	46.8	45.3	36.0	35.2	33.3	32.2	25.9	27.0
Top side	Smooth throughout							
Under side	Smooth throughout							

[a] 125 ml. of breast box stock used.

apparatus wire (with no perforated backing plate) gives practically the same results as those obtained with the sheet machine wire; and that when water is up to the wire level previous to filtration larger losses occur. The explanation for this last effect is probably that when there is no water beneath the wire, drainage commences at once while stock is being poured on to the wire; with water immediately beneath the wire, however, drainage does not commence until all the stock has been poured in and the drain cock opened, during this period some stock probably passes through the wire before draining starts. Incidentally, it should be emphasized here that breast box stock, with the excessive proportion of fines that it carries as compared with machine chest stock, was used for all these tests; if, therefore, there was any tendency for two-sidedness to occur, its detection should have been helped and the effect would probably have been exaggerated by the use of this stock.

Thus, since all the indications are that two-sidedness is not produced either by straight drainage or by drainage augmented by suction, it has been concluded that the effect must arise as a result of some special conditions that are present during drainage on a fourdrinier machine wire. The obvious target for examination here is the table rolls. When the stock rides down the wet end on the wire, presumably there is an appreciable bump as it passes over each table roll, and means for imitating this in the laboratory were devised. It subsequently transpired that the bump itself was not important, but, as will be seen, the investigations led eventually to the conclusion that composition two-sidedness is due to the water which, clinging to the table rolls and advancing under the wire, is wedged into the nip between the rolls and the wire. This water gets pushed through the under side of the wire, disturbs the under side of the sheet, and loosens and resuspends fine material which, on the suction side of the roll, is pulled out with the drainage water. It seems probable that the hump on the wire, which on most machines can clearly be seen immediately above the table rolls, may well be due partly and perhaps largely to this effect.

The investigations which first led to this conclusion will now be briefly described.

In this series of experiments, test sheets were made under conditions which enabled the wire to be jogged. The platform of the Somerville fractionator (*Proc. Tech. Sect. Papermakers' Assoc.*, 13: 37 (1932)) offered a ready means of providing this vibration movement, and sheets were made, as far as possible, under the same conditions, as used for the suction investigations (Table III), but with the addition of the vibration. The consistency apparatus was placed complete on the fractionator platform, but in the case of the sheet machine (5¼-in.) only the gridplate with its special short sheetforming cylinder could be put on the fractionator platform so that the conditions of drainage were somewhat altered but not in a way that would interfere with the conclusions. Sudden suction, where noted in Table IV, was applied to the sheet machine sheets in exactly the same way as for Table III, the grid plate with the formed sheet on it being transferred to the shallow trough for the application of the vacuum. In the case of the consistency apparatus, vacuum was readily applied *in situ* to the conical drainage water

receiver. As before, the vacuum used throughout corresponded to a minimum of 25 in. of mercury. The results of these tests are given in Table IV.

The outstanding result is that, in two cases, two-sided sheets comparable in every respect with mill manufactured paper, were made. Texture and shade differences are apparent to the same extent, and the effect can be observed both with the naked eye and under the microscope. The particular conditions required to produce this two-sided effect in the laboratory method, using news furnish and the jogging sheet machine, are:

1. *Undiluted Breast Box Stock.* If the stock is diluted, for example, with 4 parts of water, then both sides appear like an under side. It seems obvious, therefore, that a true fractionation occurs at this dilution, and owing to the mobility of the stock, short and fine material can be withdrawn from all parts of the stock as it is agitated. With a more concentrated stock, such as undiluted breast box stock, the viscosity is greater and movement within the stock is restricted so that only the fine material in the immediate neighborhood of the wire can be removed.

2. *Water Up to the Wire Level.* It is essential for water to be up to the wire level, not only when the stock is poured onto the wire, but also during most if not all of the drainage period. The fractionator is well suited to provide these conditions in combination with the small sheet machine grid plate and container, because the water level outside the sheet container can be adjusted as required. The normal procedure in making these sheets is to run water into the fractionator until the sheet machine wire is awash. The motor is then switched on to vibrate the platform and grid plate, and the stock is poured onto the wire, uniform distribution over the wire being aided by using the spreader. The fractionator drain cock is then opened at once and drainage conditions are such that there is always water in contact with the machine wire during sheet formation.

3. *Vibration.* The wire must have a vertical vibrating motion with respect to the water so that the water passes up through the wire at the bottom of each stroke. Vibration of water and wire as a whole produce no two-sidedness, as shown in the corresponding consistency apparatus experiments. In the laboratory fractionator used, the vertical movement is $^1/_8$ in. and the speed of the eccentric producing the vibration is 700 r.p.m.

Other points of interest and conclusions to be drawn from the results given in Table IV are:

1. The total loss is higher in the sheets made on the sheet machine wire with water below than in the corresponding sheets made on the consistency apparatus; this is due, as already indicated, to relative vibration of wire and water in the one case and not in the other. At breast box consistency, the under side of the immature sheet is disturbed and clay and flour are loosened and washed from it leaving a skeleton structure composed of the longer fibers. The vibration is purely a device for forcing water intermittently through the meshes. It seems probable that the same sort of effect is produced on the paper machine by the surplus water under the wire and the action of the film of water which is carried into the nip on the surface of the table rolls. Some of this water passes through the under side of the sheet, disturbs and washes it, and is subsequently withdrawn.

2. Extra suction, additional to normal drainage effects, is not needed to produce two-sidedness.

3. The fact that diluted headbox stock made into sheets on the sheet machine wire has the greatest total loss, proves that a large total loss does not necessarily mean that paper will be two-sided.

Sheets made from diluted stock were different in appearance from those made from undiluted stock. Dilute stock sheets made on the sheet machine wire were very coarse on both sides, particularly when made with water up to the wire level, where the total loss was so great (over 50%). Those made on the consistency apparatus, however, were in all cases peculiar in that the top side was coarser than the under

Table IV. The Effect of Vibration

	Sheet machine wire with its 5 1/4-in. cylindrical container				*Consistency apparatus (complete)*			
	Water up to wire level		*No water beneath wire*		*Water up to wire level*		*No water beneath wire*	
	No suction	*Sudden suction*	*No suction*	*Sudden suction*	*No suction*	*Sudden suction*	*No suction*	*Sudden suction*
Breast Box Stock; Undiluted (100 Ml.); Total Consistency 0.879%, Ash 15.8%								
Weight of sheet (moisture-free)	0.720	0.716	0.905	0.883	0.835	0.834	0.956	0.899
Ash weight (moisture-free)	0.060 = 8.34%	0.060 = 8.38%	0.102 = 11.3%	0.100 = 11.3%	0.094 = 11.3%	0.098 = 11.7%	0.123 = 12.9%	0.105 = 11.7%
Total loss, %	34.6	35.0	17.8	19.7	24.0	24.0	13.0	18.2
Fiber loss, %	28.5	29.0	13.2	15.3	20.0	20.5	10.0	14.2
Ash loss, %	65.5	65.5	41.4	42.4	46.0	43.7	29.3	39.3
Top side	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth
Under side	Coarse	Coarse	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth
Breast Box Stock; Diluted (100 Ml. in 500 Ml.)								
Weight of sheet (moisture-free)	0.523	0.515	0.745	0.710	0.895	0.905	0.911	0.873
Ash weight (moisture-free)	0.020 = 3.82%	0.018 = 3.50%	0.076 = 10.2%	0.064 = 9.0%	0.114 = 12.7%	0.119 = 13.1%	0.122 = 13.4%	0.113 = 12.9%
Total loss, %	52.5	53.2	32.3	35.5	18.6	17.8	17.2	20.7
Fiber loss, %	45.7	46.4	27.6	30.2	15.7	15.1	14.6	15.5
Ash loss, %	88.5	89.7	56.3	63.2	34.5	31.6	30.0	35.0
Top side	Very coarse	Very coarse	Coarse	Coarse	Coarse	Coarse	Coarse	Coarse
Under side	Very coarse	Very coarse	Coarse	Coarse	Fairly smooth	Fairly smooth	Fairly smooth	Fairly smooth

side, and, as Table IV shows, the effect of water under the wire in this case and sudden suction has been negligible.

The reason for the difference between dilute stock and undiluted stock sheets and also the mechanism of two-sided production will be understood from the following arguments.

In the first place, two-sidedness is produced, as already explained, using undiluted breast box stock made into sheets on the vibrating sheet machine wire. The up and down motion of the vibrating platform, on which the sheet machine wire and container are fixed, has the effect of reducing and increasing alternately the volume of stock above the wire, the water below the wire being, of course, maintained approximately at normal wire level. This rapid vibration thus has the effect of diluting and draining in quick succession the stock which is in the immediate neighborhood of the wire.

If, now, the original stock used in the laboratory is dilute, the washing process is not confined to the region immediately above the wire, because the stock is considerably more mobile and the vibration enables mixing and fiber movement to occur during drainage. The result, therefore, is that there is a larger total loss, fine material is washed fairly evenly from all parts of the stock, and the sheet ultimately formed is not two-sided but it is coarse on both sides.

The consistency apparatus container, on the other hand, although vibrating as a whole, cannot effect any alteration in the volume of the stock above the wire as the water below it is imprisoned in the cone-shaped receiver (the small drain cock being the only outlet), and there is, therefore, practically no relative movement between wire and water, and consequently no washing action.

The special cases in which dilute stock sheets made on the consistency apparatus showed a coarser upper than lower surface, appear to have been due to some sedimentation effect in which the clay, and possibly some of the fine fibers, tended to settle in the bottom under the influence of vibration. As drainage proceeded, the fine material on the under side was not washed away to any great extent, since one of the essential conditions for two-sided formation, viz., vibration of the wire relative to the water, was absent. When this condition was present, as it was in making dilute stock sheets on the sheet machine wire with vibration and water up to the wire, non-two-sided sheets were made, but they were coarse on both sides and the total loss was over 50%.

TESTING THE LABORATORY THEORIES ON A VERY SLOW COMMERCIAL MACHINE

Having now produced in the laboratory from newsprint furnish two-sided paper showing the same composition differences as paper made on normal speed commercial machines, and having also obtained from the various experiments carried out a fairly satisfactory explanation of the causes of composition two-sidedness, it was decided to arrange for tests to be carried out on a very slow 80 f.p.m. commercial fourdrinier machine, to see how the results compared with those on much faster machines.

It had been observed that, if the explanations being built up are correct, the running conditions at the wet end of this very slow machine might well be such as to produce paper, from a newsprint furnish and on a conventional wet end, which would be free from composition two-sidedness. There was, in particular, the fact that, as the table rolls revolved, water could be seen dropping down at the bottom of the rolls indicating that at these very slow speeds there is little tendency for the water to be carried up into the nip. In line with this observation, it was also seen that the very noticeable hump immediately above the table rolls on fast machines was almost entirely absent on this slow machine. This could, of course, be partly due to a much reduced suction pull on the down-running side of the table rolls, but it also could indicate that the amount of water pushing through the wire at the table roll nips was greatly reduced, as compared with fast machines, and that, therefore, the conditions needed to wash fine material from the under side and thus produce composition two-sidedness were absent. This, in fact, proved to be the case.

The normal production on this machine was a low grade heavy substance wrapping paper made for use within the mill. For the trial, however, a typical newsprint furnish containing some loading was used to make paper at a substance of around 55 grams per sq. m. (33.6 lb. 24 × 36—500) with an ash content that varied through a 5-day experimental period from about 3 to 6%. The total losses through the wire, as expected, were found to be low, about 10% compared with the normal 35% or more using the same furnish on a fast machine, and visual examination of the finished paper showed it to be almost completely free from two-sidedness (actually, due to the unavoidable use of the coarse wire required for the heavy wrapping paper, the paper showed a rather prominent wire mark which was reduced but not removed on calendering. In spite of this, however, it can be seen that there is practically no two-sidedness due to differences in composition of the top and under sides).

Confirmation of the lack of composition two-sidedness was obtained by splitting various representative sheets into two approximately equal laminations and determining the ash content. Typical results compared with the analysis of a sheet made from a similar furnish but on a different machine at 1000 f.p.m. and exhibiting the normal differences in appearance of the two sides are as follows:

	Ash content, %	
	Top side	*Wire side*
Slow speed (80 f.p.m.) samples		
1	6.0	6.0
2	4.5	4.7
3	4.5	4.5
4	6.2	5.3
5	4.2	3.7
Normal speed (1000 f.p.m.) sample	10.1	5.4

Some fuller results of the operating conditions during the 80 f.p.m. trial with examples of comparable figures at 1000 f.p.m. are given in Table V.

All the evidence from these slow speed tests thus lined up satisfactorily with the theories advanced to explain how composition two-sidedness occurs on medium and high-speed fourdrinier machines.

CONCLUSION

From the identification of the causes of composition two-sidedness, the next obvious step is to consider the possibility of eliminating or reducing the factors concerned. As will be expected, many methods, a lot of them not particularly novel, have been tried. These include the use of mesh table rolls, scrolled table rolls, doctored table rolls, table rolls with water repelling surfaces, and stripper or scraper bars instead of table rolls. The results obtained have given indications of some improvement, but there have also been difficulties, such as reduction of water removing properties of the rolls, increased wire wear, the need for driving table rolls which are doctored, and the fact that water other than that from the table roll surfaces can get squeezed into the nip. There are also two overriding considerations: the first is how really necessary is it to overcome composition two-sidedness in high-speed groundwood papers, and the second is what advantages would there be from the papermaking point of view in being able to use breast box stock, the properties of which would be substantially the same as the machine chest stock from which it is derived? The first question involves printability and appearance, and, as was noted in the introductory remarks, the printing properties of the two sides are surprisingly similar considering the large difference in composition. The second question is particularly interesting because, at the time most of this work was done, there was quite a strong call by papermakers for freer stock and these investigations appeared to offer one fruitful line of attack; but with today's faster speeds in the 1500 to 2000 f.p.m. range there has been some reversal of this attitude, and in recent years means have been sought for preventing the water from leaving the wire as rapidly as it does under modern conditions.

Since this is a symposium with full opportunities for discussion, it is hoped that these two aspects of the subject may be considered and commented upon, and also that some, at least, of the investigations, even if they have not broken much new ground, will stimulate contributions that will help to elucidate further the fundamentals of the wet end.

Table V

	Very slow machine	*Moderately fast machine*
Basis weight, g./sq. m.	62.5	61.5
Basis weight (24 × 36 —500)	38.4	37.8
Clay content, %	5.1	7.9
Speed, f.p.m.	80	1010
Machine chest stock consistency, %		
Fiber	2.10	2.58
Clay	0.22 (9.7%[a])	0.35 (11.9%[a])
Total	2.32	2.93
Breast box stock consistency, %		
Fiber	0.746	0.657
Clay	0.114 (13.3%[a])	0.163 (19.9%[a])
Total	0.860	0.820
Wire pit stock consistency, %		
Fiber	0.049	0.241
Clay	0.051 (51.5%[a])	0.149 (38.3%[a])
Total	0.100	0.390
Approximate wire losses, %		
Fiber	6	36
Clay	45	91
Total	11	47

[a] These figures show the loading expressed as a percentage of the total solids.

Laboratory Investigation of Water Removal by a Dynamic Suction Box

LARS NORDMAN

An attempt was made to study the dewatering under suction of sheets made in the laboratory by means of an apparatus that was built to facilitate application of suction for time intervals approaching those occurring on a fast-running paper machine. Suction times of 0.1 sec. and less were obtained by moving a suction box with a narrow suction slit underneath the wire on which the sheet was formed. The width of the suction opening in the box and the speed of the box determine the time of suction. The effect on the dryness of the sheet of basis weight and temperature of the sheet and of the time of suction was investigated. Dryness increases as the basis weight decreases and as the temperature and time of suction increase. For groundwood pulp the amount of fines present in the sheet has a definite effect on the dryness: a high percentage of fine fibers will decrease the dryness after suction. The freeness value of a given kind of pulp is only a rough indication of the dewatering properties under suction. The dryness of sheets made from chemical pulp decreases sharply with the beating time of the pulp, especially in the early stages of beating. Compared on a freeness basis, groundwood pulp obtains a greater dryness than a chemical pulp beaten to the same freeness value. In the case of groundwood-sulphite mixtures, the dryness of the sheets is proportional to the chemical pulp addition, the amount of beating of the pulp determining whether the dryness will increase or decrease.

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IN ALL investigations of the wet web strength the importance of the dryness of the sheet has been stressed. An increase in the dryness of a groundwood sheet from 19 to 20%, for instance, will increase the strength of the web by about 4 to 12% as reported by various authors (*1–5*). Therefore, it seemed in order first to examine the factors that affect the dryness of the wet paper web. Similar investigations had previously been carried out on a laboratory scale (*2, 6, 7*) but the testing conditions do not seem to correspond with the dewatering conditions met with in practice.

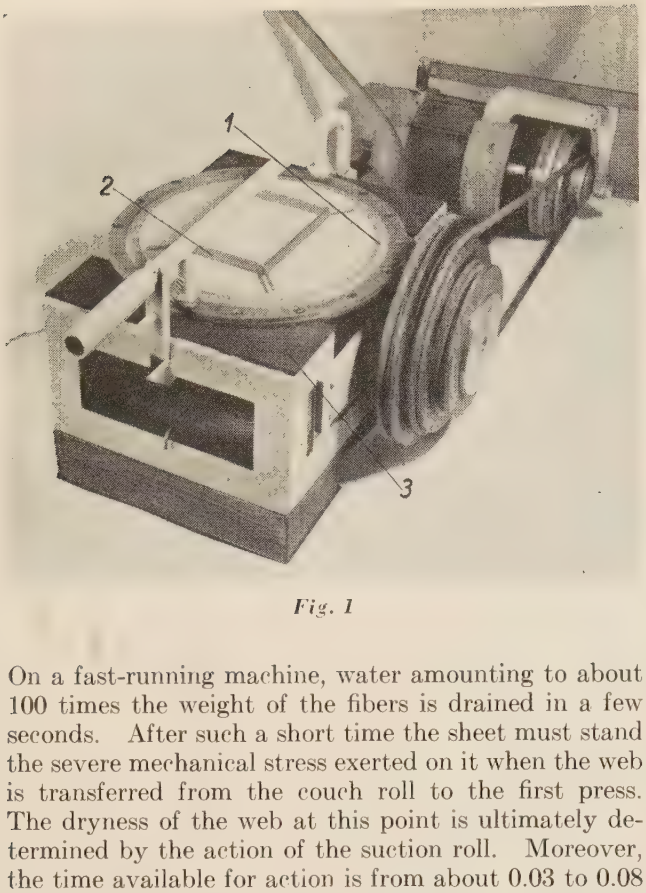

Fig. 1

On a fast-running machine, water amounting to about 100 times the weight of the fibers is drained in a few seconds. After such a short time the sheet must stand the severe mechanical stress exerted on it when the web is transferred from the couch roll to the first press. The dryness of the web at this point is ultimately determined by the action of the suction roll. Moreover, the time available for action is from about 0.03 to 0.08 second, depending on the speed of the machine. With the kind of testing equipment used so far it has been impossible to drain sheets under suction by use of a suction time even approaching the short time interval available on a paper machine. Since it has been found that the dryness increases very rapidly during the first seconds of suction and then approaches a more or less constant value, the tendency has been, in laboratory investigations, to apply suction for a time long enough, 10 to 60 sec., to allow the dryness to reach its equilibrium value. In this way it has been possible to minimize errors due to an inaccuracy of the determination of the suction time. It is, of course, true that working

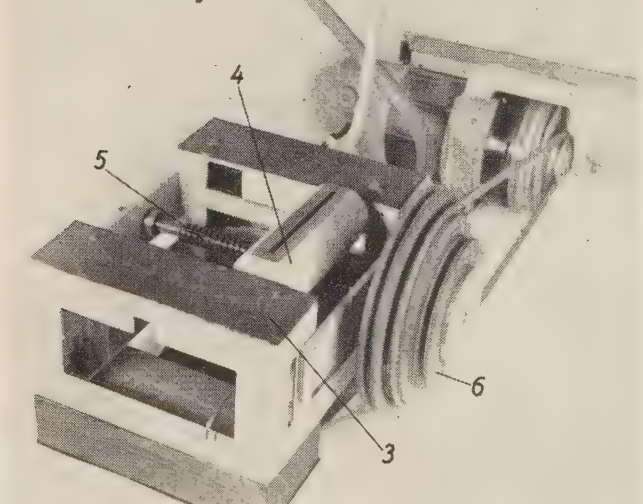

Fig. 2

on the steep part of the dryness-time curve calls for an exact time control, but on the other hand, it must be noted that the dryness of the web on a paper machine never will reach the semiequilibrium state. It is, therefore, doubtful whether a comparison of different qualities of pulp in regard to their behavior on a suction roll can be made on the basis of their dryness after a long period of suction.

In dewatering under suction two phases are distinguishable: first, when water only passes through the sheet, and second, when air as well as water is removed.

In the first phase, the pressure difference will cause a stream of water to move through the capillaries of the sheet. The surface tension of the water and the fric-

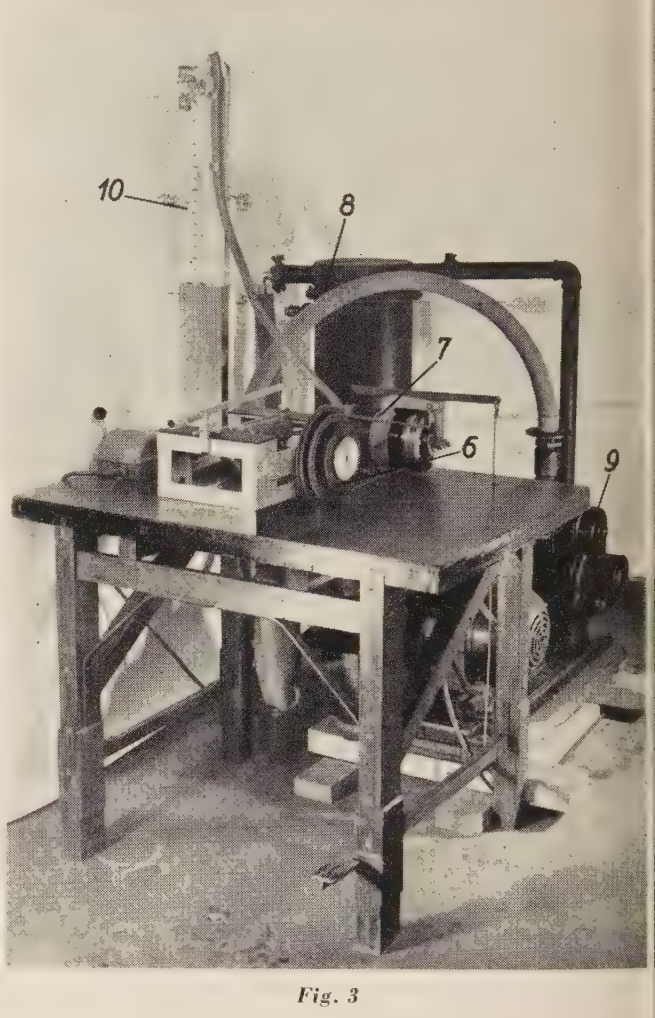

Fig. 3

tion between the water and fibers will compress the wet fiber mat. The compression goes on only as long as a continuous water front moves in the sheet. At this stage a high compressibility of the wet fiber mat is advantageous since a highly compressed sheet contains only small, water-filled capillaries between the fibers (*8*).

Wet fiber mats, however, are elastic, and as the water front moves downward during the drainage, the top layers tend to expand. Air will then enter the enlarged capillaries between the fibers. In the end there will be a stage where continuous air channels run throughout the entire thickness of the sheet. If the pressure difference is still maintained, a stream of air

will supplant the former streaming of water through the sheet.

The stream of air can theoretically drain the sheet in two ways: either by the evaporation of water into the air stream or by the mechanical action of the air stream, whereby small water particles are torn away and transported by the fast air stream. A calculation, however, shows that even if the air at the prevailing temperature and pressure were saturated with water vapor, the amount of water removed in this way would be negligible. The main effect of the air stream is, therefore, a mechanical transportation of water particles.

APPARATUS

For a laboratory investigation of the behavior of different pulp qualities under suction conditions similar to those existing in a paper machine, it was considered necessary to build a new laboratory apparatus. The apparatus should be designed to meet the following requirements:

1. The sheet should be formed under a comparatively low pressure difference. This corresponds to the action of the table rolls.
2. After the sheet is formed and has a dryness from 3 to 5%, suction should be applied by means of a constant capacity pump.
3. The capacity of the vacuum pump should allow the pressure drop across the sheet, when air is drawn through, to be comparable to normal vacuum values for newsprint suction rolls.
4. Each point of the sheet under test should be subjected to suction for a constant time of not more than one tenth of a second.

So that the very short period of suction required could be attained, the design of the apparatus was based on the following facts. The time interval during which a given point of the web on a paper machine is subjected to suction, is directly proportional to the width and the free space of the suction boxes and inversely proportional to the speed of the machine. The time interval will, therefore, be unchanged if the free width as well as the speed difference between the suction box and the wire is reduced in exactly the same proportion. This makes it possible to build a laboratory apparatus

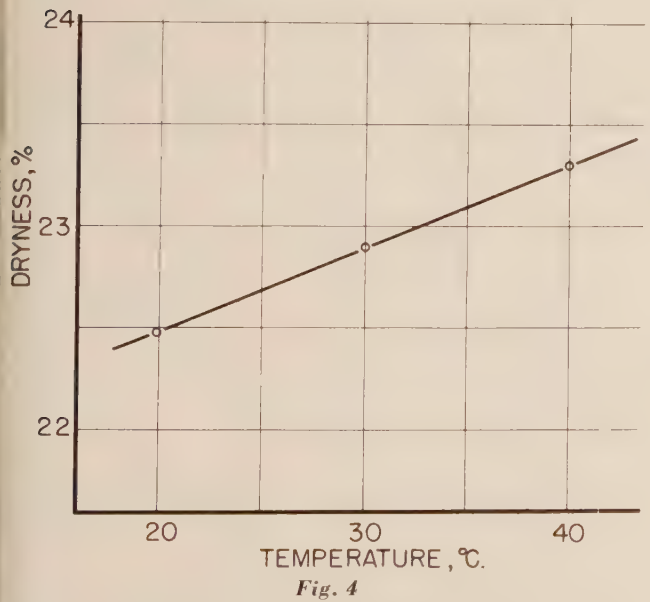

Fig. 4

Groundwood pulp. Freeness 113. Suction time 0.089 sec.

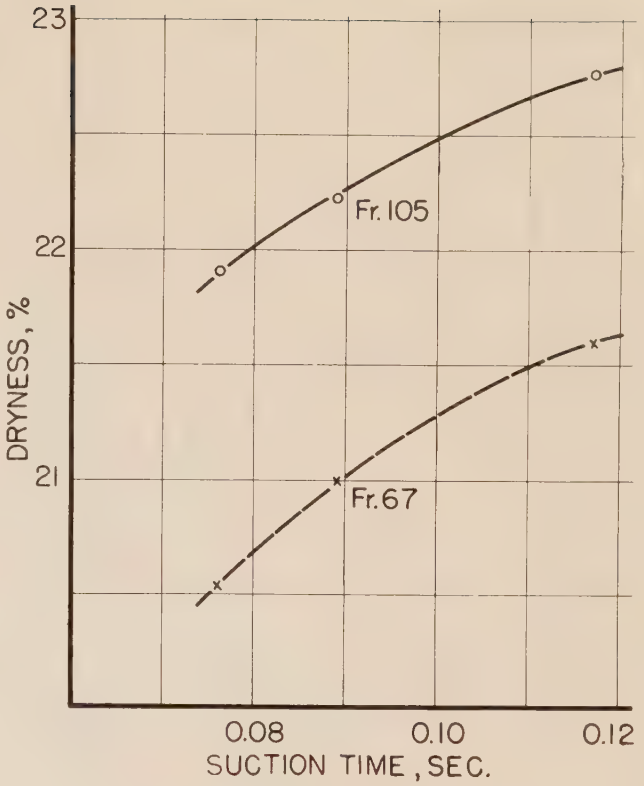

Fig. 5

Groundwood pulp.

in which the difference in speed between the suction box and the wire is controllable. If, for instance, a time interval of 0.1 sec. is desired with a free width of $^3/_{16}$ in. for the suction box, the speed difference should be 10 f.p.m., or approximately 5 cm. per sec. A differential speed of this magnitude can be easily maintained and controlled in a laboratory apparatus. In a laboratory apparatus, however, it is more convenient to have the wire stationary; therefore, the difference in speed must be obtained by moving the suction box.

Here a description is given of the design of the laboratory apparatus and the method of testing, Fig. 1. For sheetmaking a 47 by 60 mesh newsprint wire is used. The wire is fitted to the circular wire frame of a standard German sheetmaking apparatus, the Rapid-Köthen sheet mold. This sheet mold is also utilized for making the sheet, but without use of the vacuum pump of the sheetmaking equipment. The pulp suspension is drained and the sheet is formed under the comparatively low head of the pulp suspension only. This will cause no undue compression, and the dryness obtained, from 3 to 5%, will be of the same magnitude as the dryness obtained on a paper machine after the table rolls. Before sheetmaking a light rectangular frame is placed on the wire. The purpose of the frame is to limit the testing area of the sheet and to prevent water from re-entering the testing area from adjacent wet areas after the suction period. The wire together with the wet sheet and the limiting frame are then transferred from the sheetmaking apparatus to the suction apparatus. The wire frame is placed on the table and fastened to it so that the under side of the wire rests exactly on the planed upper surface of the suction box, Fig. 2. The suction box can be moved horizontally

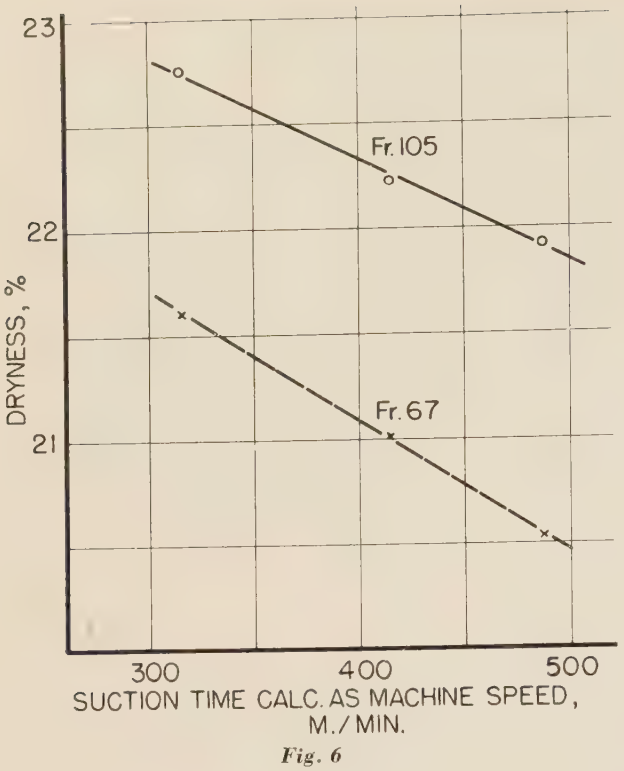

Fig. 6

Groundwood pulp.

under the wire by means of a threaded spindle and a nut. The spindle, and thus the suction box, can be given three different speeds by means of three wheels that are driven by an electric motor. Since it is essential that the suction box be accelerated to full speed before it enters the testing area, the motor, furnished with a flywheel, is kept running and is connected to the spindle by means of a friction coupling only for the test. After the suction box has passed the testing area, the motor is disconnected.

The suction box is connected through a water separator to a flap-type Alfa-Laval vacuum pump with a capacity of 25 c.f.m. (Fig. 3). The vacuum in the suction box is measured with a mercury manometer.

When the suction test starts, the suction box with the vacuum pump running is at the left. When the wire is placed on the table, the suction box starts to drain the sheet immediately, but since the opening of the suction box is outside the limiting frame, this will not affect the test. The electric motor is connected to the spindle, and the box starts to move to the right and will be accelerated to full speed before it reaches the testing area. The manometer is read while the box passes underneath the testing area. The motor is then shut off and the limiting frame removed. The sheet inside the limits is transferred into a weighing bottle for an ordinary dryness determination.

The opening in the suction box facing the under side of the wire is 4.85 mm. wide and 120 mm. long. The three traveling speeds of the box are 4.18, 5.51, and 6.38 cm. per sec. This, with the width of suction opening mentioned above, will give suction times of 0.117, 0.089, and 0.076 sec., respectively.

A statistical treatment of the dryness results obtained shows that the 95% confidence limits of a mean based on 10 single determinations will on the average be ±0.13%. This means that an observed difference between two means of 0.2% must be considered significant at the 95% level. The confidence limits for the vacuum value are correspondingly ±3.1 mm. of mercury.

To return to general remarks on water removal under suction, the two phases, water-streaming and air-streaming, take place simultaneously over the same suction opening in the laboratory suction apparatus. At the advancing edge of the suction box slit there will be a passage of water through the sheet only, while at the receding edge air as well is drawn through. Somewhere between the two edges of the slit there will be a line where air first enters the sheet. The pressure difference developed between the two sides of the sheet will primarily depend on where this line is situated, that is, on the percentage of the sheet area over the suction slit that is permeable to air. Secondly, the pressure drop depends on the specific resistance to passage of air offered by the wet sheet. The position of the line where air enters the sheet depends on the quality of the pulp. A free pulp parts easily with its water, and the line will be nearer to the advancing edge of the suction box slit, and air can thus pass through a comparatively large part of the box opening. The resistance of the sheet is consequently low, and the pressure drop, with a constant volume of air passing through per unit time, will be fairly small. In the case of a slow pulp, the part of the sheet over the slit that is sealed off by water is large, and this leads to a high vacuum value. The vacuum value read on the manometer when the box is moving is, therefore, always higher than when the box is standing still, because in the latter case air can pass through the whole sheet over the box opening, and the sheet offers, therefore, less resistance to the stream of air. As soon as the suction box starts moving, the vacuum value adjusts

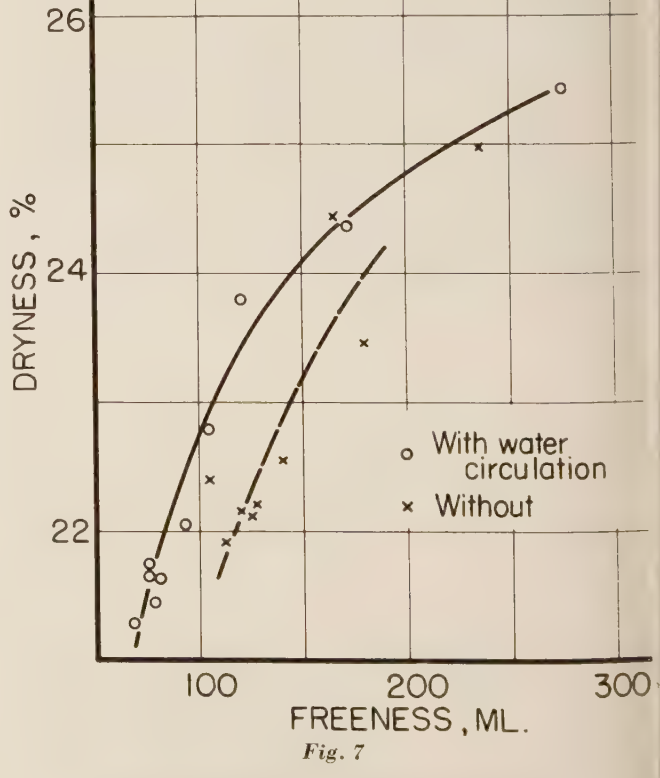

Fig. 7

Groundwood pulp. Suction time 0.089 sec.

itself to an equilibrium value, which depends on the pulp quality, the web characteristics such as basis weight, temperature, etc., and the speed of the suction box.

EXPERIMENTS

Effects of Basis Weight

When laboratory sheets are being made, small deviations in basis weight from sheet to sheet are unavoidable. It was therefore, considered necessary that the effect of basis weight on the dryness be investigated so that the errors arising from inaccuracy in sheetmaking could be estimated. The investigations were carried out over a range of basis weights from 45 to 70 grams per sq. m. It was found that the differences in dryness were comparatively small with a tendency that higher basis weights gave lower dryness values after suction. An increase in basis weight of 10 grams per sq. m. caused, thus, a decrease in dryness from 0.1 to 0.5%, depending on the pulp. These investigations were all carried out for groundwood pulp. Since the basis weight seldom varies by more than 1 to 2 grams per sq. m. in a test series, the variability of the basis weight will obviously not be a serious source of error.

Effect of Temperature

Temperature is another factor which varies considerably if ordinary tap water is used for sheetmaking. Fluctuations from 3 to 25°C. occur during the year. Temperature is, of course, a major factor in mill operation also, and it offers one of the few possibilities for bettering the drainage properties of a given pulp without changing the machinery in any way. An investigation was, therefore, carried out at three different temperatures, 20, 30, and 40°C., with a fairly coarse newsprint groundwood pulp. The results in Fig. 4 indicate that an increase in temperature of 10°C. increases the dryness of the sheet by about 0.5% and that at the same time there is a drop in the vacuum value of about 10 mm. of mercury. This is, of course, a result of the decrease in viscosity of the water facilitating a more rapid water removal in the water-streaming phase. The length of the air-streaming phase will be correspondingly increased. This can be seen from the decrease in vacuum with increasing temperature.

In the following investigations the temperature was kept at a constant value of 20°C.

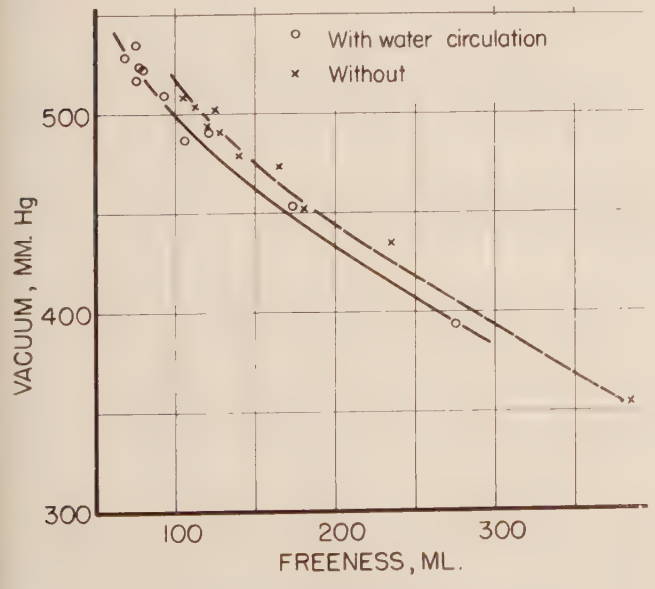

Fig. 8

Groundwood pulp. Suction time 0.089 sec.

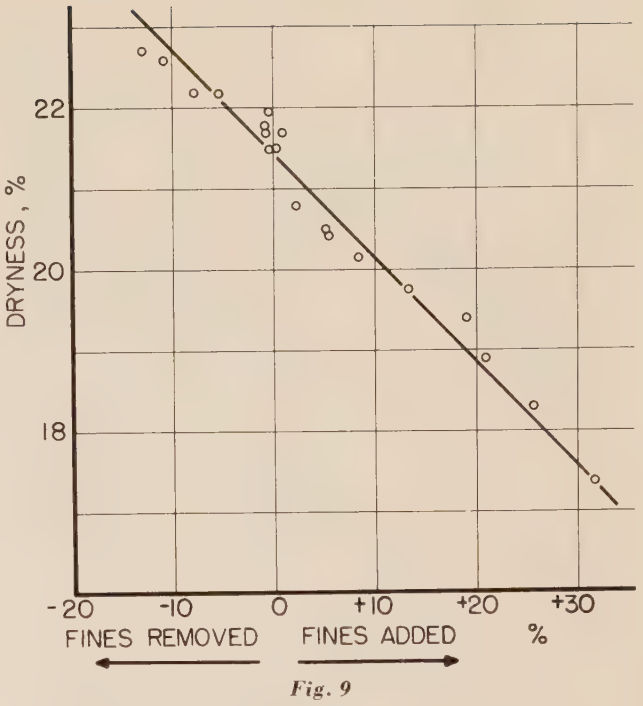

Fig. 9

Groundwood pulp. Freeness 72. Suction time 0.089 sec.

Effect of Suction Time

The purpose of the following was to investigate the effect of suction time on the dryness of the sheet. A fine and a coarse groundwood pulp with freeness values of 67 and 105, respectively, were used. The suction times were 0.076, 0.089, and 0.117 sec. The dryness obtained is plotted as a function of suction time in Fig. 5. In Fig. 6 the same results have been plotted against the calculated speed of a hypothetical paper machine with five flat suction boxes, 12 in. wide; a suction roll wet box, 12 in. wide; and a dry box, 9 in. wide, with a free space of 30%. A definite, but fairly small decrease in dryness with decreasing suction time or with its equivalent increased machine speed can be observed. In this connection it is interesting to compare the laboratory results with results obtained on the Swedish experimental machine as reported by Brauns (*9*). From two graphs for a kraft pulp it can be deduced that there is a difference in dryness of about 0.8% between a suction time of 0.06 and 0.12 sec. This difference is about the same as that obtained with the laboratory suction box. It is, furthermore, interesting to note that even a fairly large increase in machine speed, e.g., 50 m. per min., would decrease the dryness by less than 0.5%, which would correspond to a drop in wet web strength of approximately 3%. Since a newsprint machine is usually running with a safety margin of about 30% of the web strength, it seems improbable that the decrease in dryness alone could account for the increased number of breaks at

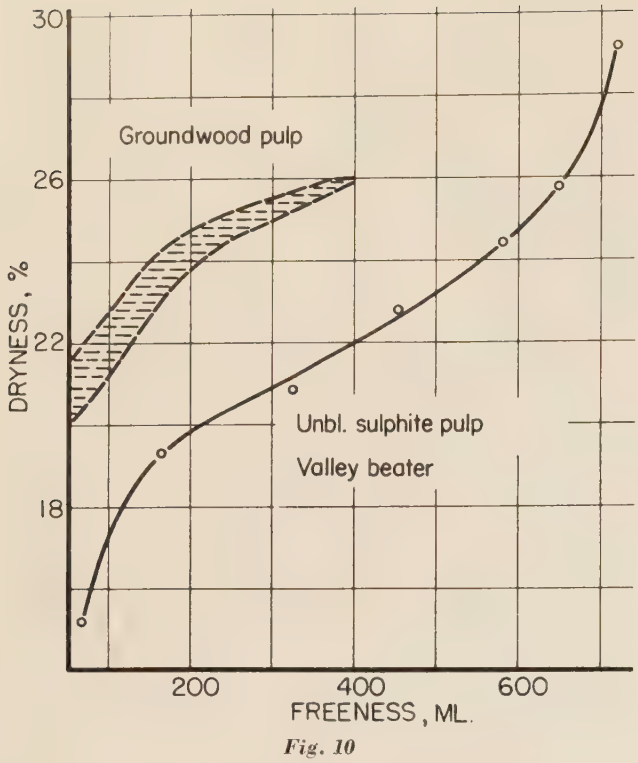

Fig. 10

the couch that is encountered when speeding up a machine.

Groundwood Pulp

One of the main reasons for building the moving suction box was to get an apparatus with which it would be possible to evaluate the dewatering properties of different qualities of pulp. However, in the case of groundwood pulp, the loss of fines through the wire is great, and a sheet formed on a coarse wire is, therefore, not representative of the pulp sample in question. On a paper machine the loss through the wire is still greater, but there the fines are recirculated and the sheet will, therefore, have approximately the same fiber composition as the pulp from which it is made. It was, therefore, considered necessary to investigate to what extent the loss of fines effects the dryness after suction, so that it could be decided whether or not a closed backwater system had to be used with the sheet mold. The Rapid-Köthen sheet mold used for sheetmaking was, therefore, funished with a closed-water system, and comparative tests were made with and without this backwater system for a series of groundwood pulps. For checking the fiber composition of the sheets after the suction test, freeness tests were made on pulp removed from the wire outside the testing area, and these values were compared with the values obtained for the original pulp. It was found that the freeness values for the sheets were considerably higher than the value for the original pulp if the backwater system was not used. If a closed-water system, however, was used, the fines content in the backwater reached an equilibrium value after a sufficient number of sheets had been made, and at the same time the freeness values of the sheets were virtually the same as those of the original pulp.

A comparison of the dryness after suction showed that there was a definite difference between sheets made with and without recirculation of fines. For all qualities of pulp investigated, sheets made with a closed backwater system showed a loss in dryness ranging from 0.5 to 0.7% over sheets made without recirculation of fines. In Fig. 7 the results have been plotted against the freeness of the sheets. It is evident that neither the dryness values nor the vacuum values for sheets made with and without the backwater system fall on a common curve. These results indicate that the freeness value does not uniquely describe the dewatering properties of pulp under suction, especially if the freeness value is affected by other factors than the grinding itself, in this case, a form of fiber fractionating. This is really quite natural, since the freeness value, determined under completely different conditions in respect to dilution and head, could not be expected to give information, for instance, about the air permeability of the wet sheet, which is a factor determining the dryness after suction.

It is striking that although the removal of fines causes an increase in dryness for a given pulp, the dryness values, as compared on a freeness basis, are lower than those obtained for pulp still containing fines. Also, in the case of the vacuum values, it is found that the order of the curves is reversed to what could be logically expected (Fig. 8). This must be explained by an assumption that the freeness value is extremely sensitive to variations in the fines content with the sensitivity being in no proportion to the actual effect of the quantity of fines removed or added.

For investigating more closely the relationship between the fines content and the dryness without making the comparison on the basis of the doubtful freeness value, the following test series was carried out. Sheets were made of a groundwood pulp by use of the water circulation system and a fixed pulp quantity. Before the equilibrium conditions in the backwater were established, contrary to the usual practice, all sheets

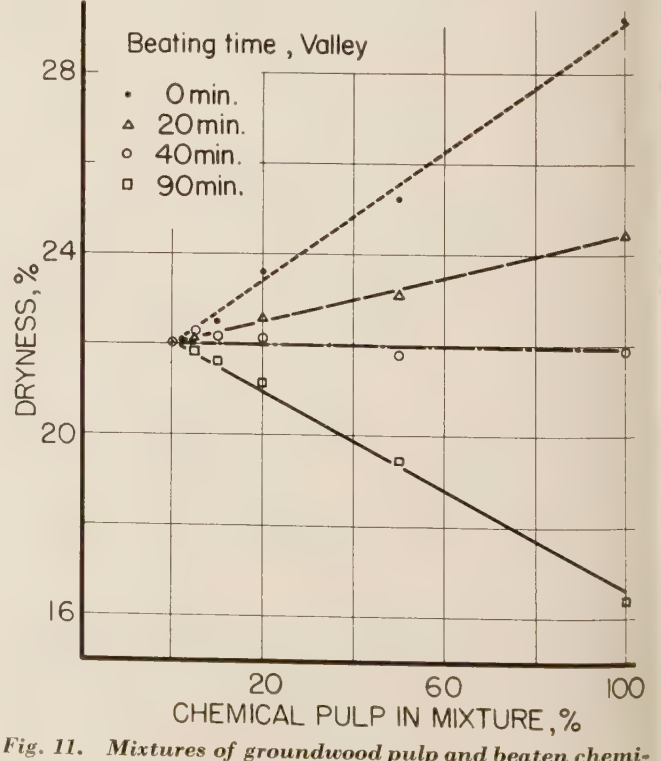

Fig. 11. Mixtures of groundwood pulp and beaten chemi-pulp

were tested starting with the first in the series. The first sheet had, thus, the greatest loss of fines. The second sheet was made by use of the circulating water which now contained a given small amount of fines. The water for the third sheet contained even a greater amount of fine fibers, etc. Each sheet contained, thus, a greater amount of fines than the preceding one in the series. This will be directly reflected in the basis weight of the sheets since the sheets were all made by use of a constant amount of pulp. The series was continued after equilibrium was reached by adding increasing amounts of fines separated from the same pulp to the constant amount of pulp used in the sheet mold. Also, in this case the increase in basis weight of the sheets will be proportional to the content of fines. In this way it was possible to vary the amount of fine fibers in the series from −15 to +30% with the zero point representing the fines content in the original pulp. The results in Fig. 9 indicate a straight-line relationship between the dryness and the fines in the pulp with a high content of fine fibers giving a low dryness, and vice versa. In this experiment the basis weight as well as the fiber composition was varied, but since previous investigations already had shown that the effect of basis weight variations is very small, the main effect on dryness is that of the fine fibers.

This relationship will have some practical consequences. A paper machine receiving at the headbox, pulp of a constant composition which has been diluted in a constant proportion with white water, the fines content of which is in equilibrium, should, after the suction couch roll, give a paper web of constant dryness. If the dilution, however, is increased, the fines content of the sheet will momentarily increase with a decrease in the dryness as a logical consequence. Since more fines than normal are transported away with the web, the fines content of the white water will gradually decrease. This leads to a gradual decrease in the fines content of the web, whereby the dryness increases. In this way a new equilibrium state is gradually attained, which is not disturbed before the dilution is changed again.

Chemical Pulp

All investigations so far were carried out for groundwood pulp. The following investigations were concerned with chemical pulp and especially with the effect of beating on the dryness after suction. In these tests the suction conditions of the laboratory apparatus were not altered in any way, and the pumping capacity designed originally to correspond to that of newsprint machines is perhaps fairly high as far as paper made from chemical pulp is concerned. In this way the stream of air will have a more pronounced effect on the dryness of the web than normally. The reason for not altering the conditions was the desire to have a common basis for comparison of these two types of pulp.

An unbleached sulphite pulp was beaten in a Valley beater to different degrees of wetness as measured by the freeness test. The results obtained have been plotted against the freeness value in Fig. 10. In this diagram the dotted area represents dryness values obtained for groundwood pulp. It is evident that the two types of pulp behave in a radically different manner when subjected to suction. Although the vacuum values developed under the given suction conditions are much higher for chemical pulp than for mechanical pulp over most of the range of freeness values, the dryness of a groundwood sheet is about 5% higher than the dryness of a sheet made from chemical pulp beaten to the same degree of wetness. This seems to be in agreement with practical experience.

The dryness values obtained for this particular pulp, as affected by beating, are typical of all chemical pulp qualities investigated. In the very early stages of beating there is a pronounced drop in dryness. This means that the dryness after suction is more sensitive to beating than the freeness value. In the freeness range from 600 to 200 ml. the decrease in dryness is moderate, but at low freeness values the dryness again falls off rapidly.

At high freeness values sheets of sulphate pulp usually obtain a lower dryness than sheets of sulphite pulp. At high freeness values the vacuum developed with sheets of sulphate pulp is much lower than that obtained for sheets of sulphite pulp, but at low freeness values the difference in vacuum becomes less pronounced, and here sheets of sulphite pulp obtain a lower dryness than sheets of sulphate pulp.

When sheets of mixtures of chemical pulp and groundwood pulp are being made, the dryness of the sheets will depend on both the amount and the wetness of the compounds. The effect of an addition of chemical pulp will be purely additive, as can be seen from Fig. 11. In this special case, where unbleached sulphite pulp beaten in a Valley beater has been mixed with an ordinary newsprint grade groundwood pulp, the effect of a chemical pulp addition is beneficial, as far as the dryness of the sheet is concerned, up to a beating time of the chemical pulp of about 40 min., which corresponds to a freeness of 315 ml. Increasing the beating time from this point onward will only decrease the dryness of the sheets made from mixtures of these particular pulp qualities. This is a case analogous to the effect of removal and and addition of fines to a groundwood pulp mentioned above. The highly beaten chemical pulp is in this respect comparable to the fines of the groundwood pulp. In both cases the dryness is directly proportional to the amount of fine fibers present in the mixture.

All these observations refer only to the dryness of the sheets. The question of the wet web strength of sheets made from pulp mixtures is more complicated, as has been pointed out by Logan (*10*) and Brecht and his co-workers (*11*). In this case the dryness of the sheet and the strength characteristics of the components may work in different directions, and it is, therefor, advisable to test the wet web strength of the sheets made from the mixtures at the particular dryness that is obtained when the sheets are drained under proper suction conditions. The moving suction box has, therefore, been used also for preparing sheets for tests on wet web strength, the procedure being the same as that applied for dryness tests.

CONCLUSIONS

In an investigation of the fundamentals of the paper machine, it is extremely difficult to find the proper scale of the equipment with which the tests are performed. The range from the freeness tester, or the ordinary sheet mold, to the paper machine is very great. In-

vestigations on a full-scale paper machine are extremely costly because of the interference with the production and because uncontrollable factors will undoubtedly have an effect on the results.

The moving suction box discussed here is another approach to a compromise between full-scale and small-scale experimentation. The treatment of the problem under consideration is the same as that applied by Wrist (*12*) in a study of the action of the table rolls, and by Sergeant (*13*) in an investigation of the headbox, that is, building a single unit where the conditions of the paper machine can be simulated and where the dimensions of the unit are such that the apparatus can be operated in an ordinary laboratory. It is hoped that by a utilization of the moving suction box, or perhaps a more refined model of it, some of the problems relating to drainage under suction can be, if not solved, at least brought nearer to their solution.

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The moving suction box was originally designed by M. Halme, formerly with the Paper Dept. of Oy Keskuslaboratorio-Centrallaboratorium Ab. The experimental work was carried out by V. Eravuo assisted by Mrs. P. Sundqvist and Mrs. L. Maatraiva.

DISCUSSION

TUESDAY SESSION, SEPT. 21, 1954

At the first panel discussion and question period, held in conjunction with the Symposium, Fundamentals of the Paper Machine, K. C. Logan was moderator.

Moderator Logan: Will the meeting please come to order? All have met the speakers on today's program. There are several discussion leaders, though, who have not been introduced. I would like to call upon Jasper Mardon, Northeastern Paper Products, who will discuss Professor Steenberg's paper to stand. Next, W. T. Bennett, Canadian International Paper Co., who will lead the discussion on Mr. van der Meer's paper. Joe Chapman, Albert E. Reed Co., will lead the discussion on Mr. Van den Akker's paper, and H. W. Bennett of Kimberly-Clark Corp. will lead the discussion on Mr. Mason's paper.

There have been a number of questions put in the question boxes. These questions will be asked by the discussion leader to whomever they are directed during the course of the discussion. But first of all, there will be a very general discussion of the papers by the discussion leaders.

The first paper of this morning by Mr. Van den Akker is to be discussed by Joe Chapman.

Chapman: With this galaxy of talent present, I feel very diffident about being asked to introduce a discussion but I will do the best I can. Mr. Van den Akker gave an extremely good review of hydrodynamic theory applied to fiber suspensions, but I think there are several controversial points that have arisen.

In the behavior of the fiber in water, it was stated that the viscous strongly predominates over the inertial forces. I would say that if that were so, then on slow running machines the shake would have no effect at all if the viscous forces did actually predominate to a greater extent. I would like Mr. Van den Akker to comment on that.

I think also that Mr. Mason does not agree that the 0.5% consistency behaves as nearly as does water. I think that it is up to the papermakers in the audience to bring the discussion down to brass tacks and point out various practical questions to ask of Mr. Van den Akker as to how he would regard them in the light of his views on the phenomena of hydrodynamics.

Moderator Logan: Thank you, Joe. I wonder if you would care to make any comments, Mr. Van den Akker?

Van den Akker: First, with regard to the relative effects of viscous and inertial forces, the theory was corroborated by the observations of Bryant and Moss on individual fibers and the point is important whenever one has occasion to think about the relative motion between *individual* fibers and water.

In consideration of the shake of paper machines, one is concerned with the fiber bundles or fiber agglomerates. As the wire shakes the most important factor is the inertia of the slurry. The most important point here is that the wire probably moves relative to the whole slurry.

With regard to the motion between the fibers and the water in the slurry, here the consistency is so high that we are not considering so much the relative motion between *individual* fibers and the water as we are the motion between fiber agglomerates and water. I think that you will find, of course, that a fiber agglomerate with its associated water will act quite differently than an isolated fiber. There are situations where technical men think and talk about the motions of isolated fibers; for these, viscous forces are more important than inertial; we should quit talking about logs.

W. T. Bennett: I would like to suggest that in our experience there is no thickening up or change in the consistency on the wire until the slurry actually forms a mat. You get a progressively thicker mat but that part above the mat is just as fluid a fluid as when it left the slice. Does that coincide with your observations?

Van den Akker: I have no personal observations on this point but I have heard many people discuss it and that certainly does coincide with the considered general opinion.

Subdividing the problem still further I would say that the effect would be the inertia of the slurry of water and fiber above the mat relative to the mat that has been formed. However, in this case and in this slurry of which you speak, the consistency is so high that the fibers do not act individually.

W. T. Bennett: That is right and I know that we will all agree on that.

A. H. Nissan (University of Leeds): I would like to ask Mr. Chapman to explain why he thinks that the shake on the machine is connected with inertia more than with viscous effects and vice versa.

Chapman: I would suspect that if the viscous forces did strongly predominate over the inertial forces, that you would get the fibers following the waves in the stock. However, there is a different effect which would indicate that the inertial forces operate.

George F. Underhay (Bowaters Development and Research Ltd.): Could we just make the point, as this business of a machine stock and machine shake has come into the picture—rather in line with what Mr. Steenberg was saying this morning with regard to cylinder machines—that the shake is an inadvertence to the papermaker who makes paper properly.

He gets his fiber on the wire, and then he shakes the wire with those fibers stuck on it in the hope that the little fibers may hit little holes where the suction is a little more accommodating, and the suction may make up a decent sheet.

W. T. Bennett: Is there any disagreement that the shake is completely ineffective over 1200 ft. anyway?

C. C. Porter (Southland Paper Mills, Inc., Lufkin, Tex.): Not from here.

Chapman: Have any papermakers any definite problems which Mr. Van den Akker can discuss? A variation in flow from the slice? How severe is that under different conditions and different consistencies? And how do you improve that?

Moderator Logan: I wonder if it might not be a good idea if we let Mr. Van den Akker have just a little while to think that one over; and we can raise that question with him later.

Van den Akker: I wish I had the answer.

Moderator Logan: We wish to cover each of the speaker's discussions in a general way, and then we will throw the meeting open for general discussion, so that it will be possible to direct your questions to any of the speakers or members of the panel. I will now pass the discussion on to Henry Bennett of Kimberly-Clark to make a few comments on Mr. Mason's paper.

H. W. Bennett: The only general comment that I have on Mr. Mason's work is that my associates and I at Kimberly-Clark all feel that it is through this type of basic work that we will answer the difficult question of what causes flocs, and how to eliminate them. I think that he is to be congratulated on his work. Later on, I do have a number of questions.

Moderator Logan: Thank you, Mr. Bennett. Next is Wes Bennett, of Canadian International Paper Co., who is the discussion leader for Mr. van der Meer's paper.

W. T. Bennett (Canadian International Paper Co.): This paper covers a very great deal of territory. Certainly Mr. van der Meer has done a marvelous job in covering such a field, and also in giving us quite a bit of factual engineering information that can be applied in actual headbox and slice design. At the same time, because of the very natural differences of opinion that exist in this room on what to expect from a headbox and slice and what kind of a design to use, there is plenty of room for discussion. There have been a number of questions handed in which will bring out various phases of design that are set forth in the paper.

There is one very obvious thing about the paper, and that is that it shows how generally widespread throughout the industry is the use of holey rolls to try to do something with stock. It shows, I think, that our knowledge of the behavior of the stock after the holey roll is still not all that is to be desired.

Moderator Logan: The discussion on Mr. Steenberg's paper will be led by J. Mardon.

Mardon: What I think we will do when we come to Mr. Steenberg's paper proper is, first of all, to take the discussion points on his written paper, and then we will have the discussion points on the paper he delivered.

Moderator Logan: I think now that we have covered the papers generally, we can now go to the questions proper. The meeting is open for discussion, either from the floor or from the panel.

H. W. Bennett: I have a question, Mr. Mason, from Mr. Cushing, of Stein, Hall & Co. In view of the many pieces of evidence that additives such as locust bean gum cause a decrease in rate of flocculation, how does one rationalize this to fit a picture of mechanical entanglement as the prime cause of flocculation?

Mason: This is a very pertinent question but one which cannot yet be readily answered. There is no doubt about the pronounced deflocculating effect of additives such as locust bean gum; ample evidence of this is given by actual mill experience and confirmation of the effect has been obtained by a number of laboratory investigations of which the latest is described in reference (*2*). We do not know the mechanism of the action of these additives and it was, in fact, with this in mind that it was stated in the introductory paragraph that "Fiber bundles are generally, *but not necessarily exclusively*, formed by a purely mechanical entanglement of fibers."

While the mode of action of these additives remains to be explained, the mechanical entanglement hypothesis does not necessarily fall down in this case. There are two possibilities. The first is that the gums become deposited on the surface of the fiber with the effect of smoothing out the surface roughness, thus to facilitate slipping past one another without entanglement, i.e., the gums act as surface lubricants. The second, but in my opinion less likely, possibility arises from the fact that dilute solutions of these gums are non-Newtonian, i.e., their viscosity coefficients vary with the rate of shear. This may have a profound effect on the rotational orbits of the fibers since the shear field existing in the neighborhood of a particle will be different from the case of a Newtonian liquid. We have not yet been able to examine either of these possibilities using experimental methods which I have described since these experiments have been carried out in a highly viscous liquid medium, not in water, to avoid sedimentation effects.

We are still trying to devise experiments which will serve to elucidate the mechanism involved with these additives, but due to a number of difficulties which I am sure you will appreciate, we have not yet been able to get at the root of this matter.

To summarize, the deflocculating effect of these materials is recognized, the reasons for the effect are not known, but the mechanical entanglement mechanism outlined is not necessarily excluded in this case.

H. J. Buncke (Oxford Paper Co): Have electric charges carried by individual fibers any effect on the flocculation of fibers?

Mason: At very low fiber concentrations and at low velocity gradients, as for example in the making of standard handsheets, it has been shown that the zeta-potential of the fibers, which can be varied by varying the ionic strength of the aqueous medium, appears to influence the formation characteristics of the resulting sheets. We have, however, found that it has no measurable influence upon flocculation in suspensions subjected to velocity gradients comparable in magnitude to those expected in the headbox of a paper machine. This does not exclude the possibility that the zeta-potential may influence flocculation on the machine wire, particularly in the last stages where the velocity gradients are damped out, but it has not yet been possible to study this under controlled experiment conditions.

R. E. Boedeker (Container Corp. of America): Would you expand on your conclusion that flocculation is primarily mechanical? Do you mean to indicate that electrokinetic potentials, etc., are of little importance in actual paper machine systems? With regard to flocculation, that is. What is the present status of thinking on electrokinetic potentials?

Mason: This question is similar to the preceding one. However, in view of the widespread view that the zeta-potential has a pronounced influence on flocculation under conditions of practical papermaking, just as it has on the stability of colloidal sols, I would like to add the following: I do not think that one can expect the zeta-potential to be important in fiber-fiber flocculation because of the large size of the fibers in relation to the dimensions of the electrical double layer. As shown theoretically by Verwey and Overbeck, the diffuse double layers involved in the zeta-potential do not exert any influence on the interaction of two particles until the particles come very close together, let us say within

several hundred Angstroms. Now if you take two fibers, of diameter 30 mu, and have them in contact under the most favorable conditions, i.e., with their axes parallel to one another, and then calculate the fraction of the surface area of each fiber which is within 200 A of the other, you will find that it is only about 1% of the total. It is this fraction which is responsible for any interparticle attraction. Now it is very unlikely that two fibers can ever align themselves in the manner described, so that in practice the fractional areas involved will tend to be very much less. As the particle size is reduced, the fractional area increases until you reach a region of particle sizes where substantial fractions of the diffuse layers become interpenetrated, and it is in this region where the zeta-potential can play a significant role in interparticle attraction or repulsion.

This incidentally, may be the reason why the formation characteristics of sheets made from glass fibers of the order of 2 mu diameter appear to be responsive to changes in pH.

W. Chen (American Machine and Foundry Co.): If the flow in the tube is turbulent rather than laminar flow, would the cylindrical fiber still line up with the direction of flow?

Mason: It can be demonstrated theoretically and confirmed experimentally that, in a simple velocity gradient of the type described in the paper, there is a preferred orientation of particles in the direction of flow; this is most marked when the particles are viewed along the Z-axis and is, incidentally, the orientation which causes the phenomenon of streaming double refraction observed in solutions of threadlike particles. The effect of turbulence is to randomize the planes of shear and thereby to destroy any preferred orientation.

J. D. Boadway (Consolidated Paper Corp.): I noticed that according to the appearance of your movies, fiber collisions lead to increase in angle λ such that a preferred orientation of fibers tends to exist with few fibers oriented parallel to the rotational axis. In view of certain debate on this point, I would ask for your comments.

Mason: This matter has been briefly referred to in the written text of my paper, and is the subject of a forthcoming publication (*8*) dealing with theoretical and experimental aspects of the orientation of rigid cylinders in velocity gradients. At the present time all I would like to state is that:

1. There is a preferred orientation of particles in the direction of flow. This does not mean, however, that all particles point in the direction of flow. Particles show $\lambda_{max.}$ values varying from 0 to $\pi/2$, but the probability density increases progressively from the lowest angle to the highest.

2. Each collision causes the particle to undergo a discontinuous change in the $\lambda_{max.}$ (or orbital constant C) which it possessed before collision. The collision may cause $\lambda_{max.}$ to *increase* or *decrease* (both are possible), but the nature of the steady-state distribution is such that an increase in $\lambda_{max.}$ occurs more frequently than a decrease.

In the films which you have witnessed several cases of an increase in $\lambda_{max.}$ by collision have been shown. Actually the reverse can also occur but much less frequently.

It is important to remember that the orientations of an assembly of particles can reach a steady-state or "statistical equilibrium," but that each particle undergoes a series of changes as the result of collisions. This is what is meant by a "dynamic equilibrium" and is strictly analogous to the state of affairs in molecular equilibria.

M. Lyne (E. B. Eddy Co.): What change in interaction was noted as the fibers used were taken from more highly beaten pulps?

Mason: Due to the complexity of the phenomena observed with fibers, it has not yet been possible to examine the influence of beating. One may reasonably anticipate, however, that beating will increase the flexibility of the fibers and facilitate entanglement in the manner described.

Ray Curtis (Scott Paper Co.): Mr. Van den Akker has shown that a fiber can be expected to follow the fluid in which it is suspended almost perfectly. Does your theory of fiber motion due to velocity gradient agree with this or do you show actual fiber movement *through* the suspending fluid rather than with it? Since fiber collisions do occur, the fibers would seem to move *through* the water.

Mason: Mr. Van den Akker was referring to the translational motion of the particles and was demonstrating by a rather conclusive argument that in translation a particle (whether spherical or cylindrical) having the dimensions and density of a fiber "keeps in step" with the surrounding liquid even when the acceleration becomes very high.

In the systems which I have described the same holds true as regards translation, but because of the presence of velocity gradients rotational movements are superimposed.

I can see no conflict between Van den Akker's statements and mine.

Moderator Logan: I wonder if anyone in the audience or panel has a different idea, anything to add to that question?

Reavis C. Sproull (Herty Foundation Laboratory): I don't believe any mention has been made of the effect of polarity on the flocculation and deflocculation. Now, particularly in the field of glass fibers, there is a very critical part or point of polarity where you get flocculation or deflocculation; and it even goes over to the wet end of the paper machine. You obtain no strength at all if your polarity is wrong, but you get a sheet that you can handle through the driers when your polarity is correct.

I am of the firm opinion that polarity has more to do with it than mechanical entanglement. Therefore, I am taking issue with the statement that it is primarily entanglement. How about polarity?

Van den Akker: Could I raise a question as to whether John Swanson would have something to offer?

John Swanson (The Institute of Paper Chemistry): I would like to use the blackboard for just a moment to point out several things which were done along this line by Erspamer. They have a bearing on this problem.

One of them is this: If one places the fibers at consistencies of 0.01 to 0.03% in a sheet mold, and stirs them up, arrests the eddy currents as well as can be done, and then allows the fibers to continue flocculation up to the moment the sheet is actually formed, a straight line, or nearly so, is obtained when a plot is made of the formation number of the sheet as a function of the elapsed time. Now, the Thwing number up here (indicating) might be 65 and the slope of the line will be something like you see here, out to as much as a hundred seconds of time in the sheet mold.

If the fiber consistency is increased in a similar experiment, then the line will start out here at a lower Thwing formation value but, the slope will be greater. At higher fiber consistencies (0.05 to 0.1%) the pulp appears to flocculate very rapidly at first and then jells so that the fiber motion is arrested.

Now, if a fiber deflocculating material such as 1% of locust bean gum is added to the pulp the curve is raised and the slope is decreased. The only effect of the gum as far as we can tell is simply a slowing up of the rate of flocculation. That, of course, thus does not throw any light on the mechanism as such.

If small amounts of aluminum sulphate are added and just traces are sufficient, the curve is lowered. Now, if a series of sheets is made with locust bean gum and a constant quantity of alum is added in every case, then the curve is also lowered. However, the curve is never lowered to the curve of the original pulp. This illustrates that the gum does have some residual effect, even though we have added enough alum to cause quite a serious flocculation of the pulp.

On the other hand, this holds only for locust bean gum. There are certain other fiber deflocculating agents which do not function at all in the presence of alum. In some cases, the mere trace of alum will make the flocculation worse than it would have been without any deflocculant. However, these

materials are chemically different. They are polyuronides whereas the locust bean gum is a mannogalactan.

I would also like to discuss some experiments performed by Erspamer a number of years ago which have to do with the zeta-potential and its possible suspended effect upon fiber flocculation. Fibers were suspended in water, in ethyl alcohol, in nitrobenzene, and in pure benzene. Determination of the so-called zeta-potential of cellulose fibers in these various media have been made but I don't know how valid are the results. However if we accept them as showing difference in fiber zeta-potential in these various media then the zeta-potential in benzene is zero, in alcohol (−40 mv), it is greater than that in water (−20 mv), and in nitrobenzene it is greatest of all (−140 mv).

We now come to the crux of this whole experiment. Erspamer found it was almost impossible to disperse the fibers in benzene, whereas they flocced more slowly in water and ethyl alcohol, and hardly ever flocculated in nitrobenzene. If hydration or swelling has a bearing on the matter we would expect the water to give us a better fiber distribution than the ethyl alcohol. However, Erspamer found flocculation of fibers to be slower in ethyl alcohol than in water.

Moderator Logan: Mr. Bennett, would you like to advance some questions or if not, I am sure that there will be some from the audience?

W. T. Bennett: There are quite a number of them here and I think that the first one should be easy for Mr. van der Meer to answer.

The first question is: "What causes alignment of fibers in the machine?"

Van der Meer: I think that you have, first of all, seen from the slides that it is not necessary that the fibers lay in a certain direction. However, on the other hand, it is very difficult, especially with high-speed machines, to have equal speed of stock and wire. When these two are not equal you never can get what we call a square paper. Third, then you may get a random orientation of fibers and you will have an ideal square paper. I hope that this is enough.

W. T. Bennett: I think that is enough because I think that the audience generally agrees with what you said and yet there is plenty of chance to disagree with you if they want to and plenty of chance to argue with them all night. Therefore, it is now time, if it is agreeable with you all, to go on to the second question.

I don't think that I need to read the question but it has to do with the drag of friction on the front and back side of bond plates.

The question came from Harry Buncke of the Oxford Paper Co.

(Mr. Van der Meer then answered the question by illustrating the answer on the blackboard by the drawing of a diagram.)

W. T. Bennett: You know, sometimes a gentleman will ask the question when he knows very well what the answer is before he asks the question. I would like to ask Mr. Buncke if he had some other solution in mind when he asked his question.

Buncke: I would like to say that the holey roll I have in mind is the design that Mr. Van der Meer has described in his diagram. The support is quite a way from the end and I think that Mr. Mason said this morning that 0.5% stock generated a friction of a 0.5 lb. per sq. ft. drag if I remember correctly, at the contact surface. So it looks as though we have to introduce something to overcome that condition. What I had in mind is the possible suggestion of substituting hydraulic friction at the edge rather than contact with the side, by having a bleed-out at the side of the pond plate—hoping that in some way you could reduce the retardation of the velocity as it passes through the slice ends at front and back pond plates.

Van der Meer: What speed do you have?

Buncke: The machine speed runs at 1250 f.p.m. The practice usually followed is to try to get the slice up a little bit more at each end so that you can let more stock through.

Porter: I would like to make a point there. I know of two machines which have padded pressure boxes and, in answer to your question as to the best method, the operators' experience was that it was easier to bleed from the side and avoid permanently deforming the lip at the outside edge because they could not put too much adjustment into a very short space. You would have to have a space of 2 or 3 ft.

W. T. Bennett: It has been stated that paper fiber suspensions exhibit greater dynamic viscosity than that of water. Is there any experimental evidence concerning the nature of this increased viscosity? For instance, does the viscosity of the suspension depend upon the distance from the wall of the vessel? Is it possible to obtain the usual velocity distribution characteristic of steady laminar flow of a homogeneous fluid through a pipe? That is by Mr. Nicholl of the National Research Council.

Mr. Brecht, would you like to comment on the question on the viscosity of the stock and whether it is possible for the stock to have a laminar flow?

W. Brecht (Institut für Papierfabrikation, Darmstadt, Germany): I believe that Mr. Van der Meer refers to work we did years ago. At that time we found interesting things which we could not explain and we were quite excited. We found what you know from other work too, that with consistencies of about 0.5 to 0.8%, the loss of friction in the piping was less than at higher consistencies and especially was less than water without any stock. Incidentally, we only could explain it by assuming certain kinds of tubings. However, we did not continue with this work and therefore I do not think that I am able to go further.

W. T. Bennett: I think that you are referring to very much the same information that Mr. Van der Meer gave in his paper this morning. Possibly Mr. Nicholl would like to comment a bit further on that question and tell us what he has in mind.

I. H. Nicholl (National Research Council): I just wanted to ask whether in a suspension of these fibers which presumably contribute to momentum transfer, if the momentum transfer is similar to that in a homogeneous fluid? It would seem to me that if one has to design any hydrodynamic device such as a headbox one would want to know whether this increased viscosity is in fact isotropic in its action or whether there is an anisotropy because of the presence of the fibers, in the action of the viscosity? I was just wondering if anybody had checked whether this was the ordinary parabolic distribution?

Van der Meer: I would say this—Mr. Nicholl has said something about it already, and in the same section where we were discussing this work of Mr. Brecht—there you can find some curves of velocity distribution.

I have also made investigations on that, especially on the anisotropy, and we found at lower viscosities we had a sharp velocity gradient at the side; in the middle—a uniform velocity.

Nicholl: That is laminar flow?

Van der Meer: No, plastic flow—the stock particles are not moving along each other. You could make a painting on it for it doesn't change.

W. T. Bennett: Mr. van der Meer, you might mention that we use different terms. You are describing what we call a "frozen flow"; and what somebody else called, this morning, a "plastic" flow.

Van der Meer: "Plastic flow" is the same.

At higher velocity, the zone with velocity gradient at the sides, becomes broader, until we get a full parabola over the whole width. V. P. Mead has made investigations on "viscosity" and shear gradient and we can say according to these, we will have a lower "viscosity." On the other hand, we

cannot speak about viscosity, as this fluid has Bingham properties.

The question is, what do we mean by viscosity? I mean this—when you speak of a viscosity, that is nothing, for it depends on the diameter, on the length. When I take a certain shear in a canal of a certain width, I can find any number that I may call a "viscosity"; but when I take a system, which is twice as big, or we will say three times as big, you will find a viscosity, or a number that you call a viscosity. So, where are we going? It is a Bingham fluid, and not an absolute.

VAN DEN AKKER: Mr. van der Meer, I would like to applaud your remarks. I don't believe "viscosity coefficient" should be used.

VAN DER MEER: Yes. It is not a certain fixed number.

VAN DEN AKKER: It is so far from being fixed there is no utility in employing it.

I don't know why old work has to be forgotten. Some of the oldtimers will remember the work of Sigurd Smith, away back, I suppose it was around 1920. He showed that it was much more useful to employ a frictional traction stress.

What we are talking about here seems to be analogous to comparing something like Coulomb friction with classical lubricated bearing theory, for example, and the two are just miles apart.

VAN DER MEER: Where you have, for instance, a glass vessel, and you can see what occurs, then when you speed up the flow, the stock begins to roll along the wall. It is running on roller bearings. What, then, is viscosity?

W. T. BENNETT: I think probably we of C.I.P. are the only ones that are actually employing what we call "frozen flow" on commercial headboxes. Now, when you do that, you have a horizontal canal leading to the slice, in which there need be nothing, literally, except some stock, and perhaps some air above it. You reduce the turbulence in the flow to zero. If a machine, then, is say 23 ft. wide, as our Gatineau machines are, and you look at that flow, it appears, as Mr. van der Meer says, that you can paint a picture on it in all but about a quarter of an inch shear zone adjacent to the fixed surfaces. As far as we are concerned, we squirt off that. Paper is not made at that shear zone and it is therefore of no consequence. All of the rest of the stock is traveling forward at the same velocity, and with no internal movement.

Just one other comment, because it interested me so much, Mr. Van den Akker. You described the way the fibers gather together in flocs when the relative velocities are extremely low, and that is exactly what happens in our big machine headbox. Just at the time when the last of the turbulence is dying out—and it dies out due to an acceleration which we purposely apply, the stuff goes into flocs. It is for that reason we have to use "defloccing rolls," as we call them. And all we do is create a slight turbulence to reduce the floc size, and then we allow the stuff to become frozen before it reaches the slice.

Another thing that interested me—and it is certainly related to the same subject—and Stan Mason can correct me if I am wrong—I wouldn't know a zeta-potential if I saw one. We are delivering stocks with a commercial headbox with zero relative velocity between any of the fibers. If there were a few zeta-potentials around, shouldn't they do something to that stock? The only thing that does act on it, when you get it into that condition, or at least that we can see, is the air on the fibers—so, it has been our practice on all these machines to take the air out.

MASON: I think that the basic principle that you described is very sound. What you are doing is removing velocity gradients from the system. You are thereby removing the means whereby fibers can collide with one another and become aggregated.

W. T. BENNETT: Just before they die out, we get that mechanical entanglement—just what you were talking about, as far as I am concerned.

C. M. CONNOR (W. C. Hamilton and Sons): I would like to ask Mr. Bennett if he accomplished this frozen flow by the hydrodynamics of his design, or whether it is some trick that C.I.P. has other than that?

W. T. BENNETT: There is no "trick." The method is described in the Canadian patent which has been published. The only thing different about the method that we use to get the frozen flow from what all of you are using and what Mr. Van der Meer has described, is that, having created a certain intensity of turbulence, we provide fixed surfaces for the kinetic energy of that turbulence to be worn out by friction on the surface, thereby dissipating the energy of the turbulence, and putting the stuff in a condition to freeze. We do that in the tube system which has been described.

Now, that is the only point of difference that I can see in it. The introduction of sufficient fixed surfaces to wear out the kinetic energy that is left when you put a flow through an orifice, or a multiple series of orifices, and convert static head into the velocity head; and then when you put the stock into a large area, and the velocity drops, only part of the velocity head is brought back into static head—the difference goes into this uncontrolled turbulence, which I think you were describing this morning.

MODERATOR LOGAN: I wonder if there are any others who would care to comment on this subject?

H. W. BENNETT: This is rather a hard one on which to comment. I think that the fact that if you look at the stock and don't see any large eddies, is possibly not a true indication that the flow is actually laminar or plastic. The large order eddies that you occasionally see coming out on the wire are not really turbulent flow in the classic definition. Turbulence as such is not at all well ordered; it is extremely random, and behind your rod roll, or "cage" roll that you speak of—it is of an extremely small scale.

In other words, the relative motions are extremely small, and I doubt that you would be able to see them by looking at the flow.

It is a very interesting problem, and needs investigation; I just doubt that at that value of the velocity, and in that large a hydraulic structure that you do have laminar flow.

W. T. BENNETT: Have you ever seen one of these operating?

H. W. BENNETT: No, I haven't.

MODERATOR LOGAN: I'm sure Wes Bennett would give you an invitation.

H. W. BENNETT: You stated, I believe, that you get a very low value of turbulence by keeping the roll extremely open. In other words, you only have a few rods. I think that by modern turbulence theory that you would find that the intensity is pretty much a function of the size of the rod, and it is, well, as I said, it's something that ought to be investigated thoroughly.

W. T. BENNETT: The defloccing roll that we use was invented by Robert Duncan. During the course of the testing and the relative work that he was doing on headboxes, if there was any combination of rods, sizes, percentages, of open area, that he didn't try, I'd like to known what it is.

Now we think that turbulence is reduced to zero before the defloccing roll, and again soon after the defloccing roll, so that when the flow approaches the slice orifice, the turbulence is zero.

MODERATOR LOGAN: Is there any further comment on this particular question?

NISSAN: I am afraid I'm not very familiar with this problem, but is the stock flowing over a stationary surface, or a surface which is moving at the same speed as the stock? Because, if it is a stationary surface, the top may be frozen, but surely the bottom of it is the same design of that thing.

W. T. BENNETT: I don't think I'm competent to answer that. As I told you, you can easily see what happens on the side of the box. There is a thin shear zone about a quarter of an inch thick. It is reasonable to assume that such a shear

zone would exist on the bottom. And when we were working on this thing I fully expected that we would have to peel that off, just like you would have to take the peeling off an orange and throw it away. But there is no evidence that it exists in the actual machine operation.

NISSAN: Could I ask how deep is the stock?

W. T. BENNETT: It is normally on one machine, at a flow speed of 1200 ft., about 7 in.

PETER E. WRIST (Quebec North Shore Paper Co.): After having seen the box I can assure you the condition of frozen flow does exist, and that where you do get some relative motion between sides, it is restricted to within about half an inch of any surface, and so you have along each surface of the box a half inch where there is relative motion.

If there is a supporting disk in the deflocing roll, there is a relative motion along that surface; but elsewhere there is no relative motion that you can see; if you can't see it, then you needn't worry too much about it.

C. A. LEE (Kimberly-Clark Corp.): I think there is a point here that W. T. Bennett made that should be emphasized. That is, that the stock entering their deflocculating roll enters in a flocculated state, and that the roll, if I understand the operation of the inlet properly, does create turbulence during the rotation of the roll, and thereby isotropic turbulent motion of the fluid. Deflocculation then results.

I think the fact that the fibers or flocs are subsequently frozen; that is to say the turbulence resulting from this roll action decays before the slice, is somewhat academic in the whole consideration of the problem.

J. E. IRVINE (Abitibi Power & Paper Co., Ltd.): I am going to depart a little from the frozen flow box. I would like to ask Mr. Van der Meer a question concerning his Fig. 15A, that is the vertical slice, in which you stated that the vertical wall will give vortexes an opportunity to be generated. Do you speak from actual experience or experiments concerning such a slice?

VAN DER MEER: We have a flue that is 2 ft. wide and 2 ft. deep. In that flue we have made a vertical shield of Lucite so you can see this very well.

IRVINE: You actually can see the vorticing?

VAN DER MEER: Even when you couldn't see it on the surface with special lighting, the whirls were detected by adding colored stock.

IRVINE: What velocities were you using?

VAN DER MEER: About 1 f.p.s. as a mean approach velocity. Near the wall it was, of course, less.

W. T. BENNETT: We are seeing the same thing. Lots of times we have seen the air as bubbles coming out at the slice lip, and in that case, the approach flow would all be the same, 1 or $1^1/_2$ f.p.s. As it hits a vertical slice, it almost always makes eddy currents or vortexes, and if it happens to be an air-loaded box, some of the air loading will sneak down through the hole and go out the slice lip.

IRVINE: The pressure actually from the air compressor.

MODERATOR LOGAN: There will be a lot more discussion on this paper, I am sure, but I think it would be only fair to move on to Mr. Steenberg's paper, and have a few comments and questions concerning that.

MARDON: First of all, there are a number of small hydraulic points which I would like to question Mr. Steenberg, concerning his model. One of the things that appeared is that he has neglected the effect of the velocity along his box in computing his head. Although I suppose that is perfectly reasonable, in fact, a small effect, I would like to hear from him concerning that.

STEENBERG: In page 3 in my paper, it is stated how the making head was defined; and there you have all the terms in the Bernoulli equation, together with other information. The words "making head" used later on really comprise both terms.

MARDON: Another point is the question of the proportionality between the rates of flow. Is that accurately given, in fact, by the ratio of the two areas? I'm not saying that it isn't; but it occurs to me that presumably there is some verification of that, because just by comparing the two areas, one loses the effect of the frictional entry losses and those of the siphon.

STEENBERG: Yes, this is something that had to be introduced in order to make experiments. In a paper machine you have free outlet for the water on the inside of the wire; but if we had that, we would get such a tremendously rapid sheet formation, which is, of course, what you want to have in practice, but we couldn't possibly get any readings.

There was only one way, and that was to restrict the outlet; and of course, an essential part of a setup of this type is to exaggerate all possible effects to evaluate them. And that is something you will find right through the paper. You cannot expect the effects mentioned to have the magnitude they have in these experiments, because the experiments are specifically designed to exaggerate all differences or all effects that possibly could be found.

MARDON: I hope to, in passing, point out that I am merely putting these things up because I thought they were points that could be amplified. It is not necessarily that I believe them myself, but I wanted to get Mr. Steenberg's explanation into the record.

STEENBERG: Thank you. It should have been stated here, I actually think it is not so bad for those who have read the paper as it is for those who heard my talk on it, because in the paper it is specifically said that it is tempting to draw practical conclusions, but that these should be, as much as possible, avoided. I didn't avoid them in my talk.

MARDON: The next point is the strict justification for assuming that the rate of flow across the probe is the same as the average. I suppose that Mr. Steenberg has in effect made measurements across his box?

STEENBERG: Of course this is, again, very difficult to make, because you can never have your wire in perfect alignment with the surface of your box.

MARDON: One other point that occurs to me is—it might be that the effect of turbulence, which is much greater in the counterflow vat, gives you a different distribution of stock; and the anisotropy of the counterflow vat is, I believe, much worse than the uniflow.

STEENBERG: I like to distinguish between strength orientation and fiber orientation. I think that there is no doubt that they are partly independent properties. The fiber orientation given here is based on the requirements of the orientation of dyed long fibers.

The average orientation of all fibers of different lengths may not be the same as the orientation of the long fibers which are the only ones we can measure.

MARDON: This is a question from Edgar Carpenter of the Weston Paper Manufacturing Co., who has asked Mr. Steenberg a question on the effect of a Minsky attachment or Foley vat on a counterflow cylinder.

STEENBERG: If that arrangement isn't known to you then I want to show you how it works. It is a counterflow system. It takes out the stock from here (indicating) and reintroduces it up here (indicating).

I think that all of the criticism that I gave on the other types of mixings must apply also to this because here again you are drawing a stock of one composition and mixing it with stock of another composition. It seems that the criticism of mixing in this device, as well as the others, is justified. Stocks of different composition are difficult to mix. If the mixing is perfect, it will work. I doubt whether you can do it.

CARPENTER: I happen to be the one who submitted that question. One reason that we submitted it is that we used the Minsky attachment and we found that we can get a much better formation with the attachment than without it. It is something that I hate to place a definite value on but it is on the order of a 15% improvement as a reduction of thick and thin spots and so forth.

One reason that I wanted to ask that question was in view of your statement that we should not get that improvement. However, we did get it.

STEENBERG: Then in all probability you are the first man that I have heard who has been happy with this arrangement.

Secondly, it is really a question of how well you mix the stock that comes in here (indicating). It is a question of how will you mix and, of course the proportion of this flow (indicating) in relation to this flow (indicating). You might be able to change it.

MARDON: There are two more questions on the matter of fiber alignment and I think that perhaps Mr. Steenberg could answer them at the same time.

STEENBERG: I think that the cylinder machine is an ideal machine to produce fiber alignment: first, because you have a combing wash-off effect in your vat, and secondly, you put it on a felt and stretch it so that you get an additional effect.

It is well known in Sweden, where a large quantity of twisting paper is being used and made, that it is impossible to make twisting paper with a completely closed felt system.

To obtain sufficient machine direction in the sheet you tilt the wire—which is a standard practice on slow machines. You will, however, not be able to get the required machine direction by this method alone. If you have an open draw, preferably in the first press part, you can get the required machine direction strength.

ALLEN A. LOWE (The Sandy Hill Iron & Brass Works): I would like to have Mr. Van den Akker reconcile the feeling that the fiber doesn't align in the flow and the necessity of doing something about the alignment of the fiber in the flow or making a grainy sheet.

VAN DEN AKKER: Mr. Lowe, are you speaking of the fiber alignment in the paper web?

LOWE: Yes.

VAN DEN AKKER: The comment that I made had to do with the lack of fiber alignment in the flow of a slurry in a channel or a duct.

Now, there is an aligning effect in zones of acceleration. In a zone of acceleration (as in the slice) there is a partial aligning effect which probably has some relation with the partial fiber alignment in the paper web. The comment made in the first paragraph of my paper related to the absence of fiber alignment in a slurry during uniform flow.

RAYMOND A. HILL (Congoleum-Nairn, Inc.): I would like to ask Mr. Steenberg a question. He has spoken several times of wash-off effect which most of us have seen on cylinder machines but I don't believe that he got to the point of stating just exactly where it occurs or what you do about it.

I have often thought that a good deal of it occurred where the cylinder turns out of the vat but I haven't been able to prove it.

STEENBERG: Well, you actually have two types of wash-off and I only speak of the one that happens when the wire is really submerged. The wash-off effect that I am speaking of is the one which is proceeding practically all the way along the wire.

However, you also have a secondary effect of the same type, which is when you start to pull it out from the water and carry it up. That is where it goes up and part of it slips back. Now, I do not call that "wash-off," I call it "slip-off." That effect is sometimes even more worrying than the wash-off effect.

Now, on the slip-off effect, you can improve that by a fairly moderate vacuum. Probably at home you are using an ordinary fan.

I think that the main reason for having large diameter vats is because of this critical angle here (indicating). You have the problem of taking the sheet, which is extremely wet out of the stock and carrying it up into the air and over into the horizontal position without having the slip-off effect, and that is where the large diameter helps you and that is, of course, where the small vacuum inside helps you somewhat.

Is that a good answer to your question; would you want to have more or what is the question that you asked?

HILL: That is part of the answer to my question. I don't think that to continue this discussion here would be of any further interest to this group. We do use the largest diameter of cylinders that I have seen and we have used vacuums from a tenth of an inch of water up to 7 in. of mercury and we still have it slip off.

The following written comments by E. R. Finger and Z. J. Majewski, on the paper, Australian Paper Manufactures, Ltd., presented by Mr. Steenberg, may be of interest to the readers. Unfortunately, time did not permit their consideration.

1. In the model the stock moving under a stationary wire gives a "rolling over" effect to the fibers being deposited.

In uniflow vats the stock velocity is usually less than the wire velocity so that the sheet is formed under a positive drag.

The "rolling over" nature of the deposition of fibers in the model simulates to some extent conditions in a contraflow vat, with the difference that the relative velocities studied are much lower than those experienced in practice. The maximum velocity investigated was 100 f.p.m. whereas in the contraflow vat this may be as much as twice machine speed. This would explain why the strength orientation and other properties obtained in the model were so different to sheets formed in contraflow vats.

2. Could you please expand on your opinion that the possibility of varying the making head during the sheet formation process is important on commercial machines?

It appears to us that there is a big difference in the making heads used in these experiments and those used in commercial machines. In the model the actual rate of flow through the wire at the beginning of formation would be produced by a head across the wire equal to the head h applied to the siphon divided by the square of 78, which is the ratio of the areas of probe wire and siphon tube bore. The maximum head employed was 200 mm. giving a head across the wire of 200 divided by 6084, which equals 0.033 mm. or approximately $^1/_{1000}$ in.

3. The relationship between density and basis weight, as shown in Fig. 13 is rather surprising, as one might expect that, rather than rapidly increasing with basis weight, the rate of increase of density would rapidly decrease with basis weight. After an initial layer of fibers is deposited, more fines would be retained in the sheet, but the rate of drainage would rapidly decrease, so that the fibers would become less densely packed. Then the higher the basis weight the lower would be the average density. Even if a selective deposition of shorter fibers takes place one would expect some leveling out of the curve. Close examination of the results tabulated, but not plotted in the graph, would appear to support this idea.

4. The authors have demonstrated in an excellent manner the washing off of fibers which follows the initial stage of formation and that this is a selective process. However, with regard to a commercial machine a very interesting question arises, what happens to the long fibered stock rejected from the sheet after the initial stage of formation? A vat working in a state of equilibrium must produce a sheet with the average fiber length of the stock supplied. The mechanism is particularly interesting in uniflow vats, where the forming sheet contacts stock of steadily increasing concentration, because the continuing drainage is not accompanied by further fiber deposition.

It appears that the stock concentration will always be higher at the surface of the formed sheet than the measurable average stock concentration. At the point of separation of the

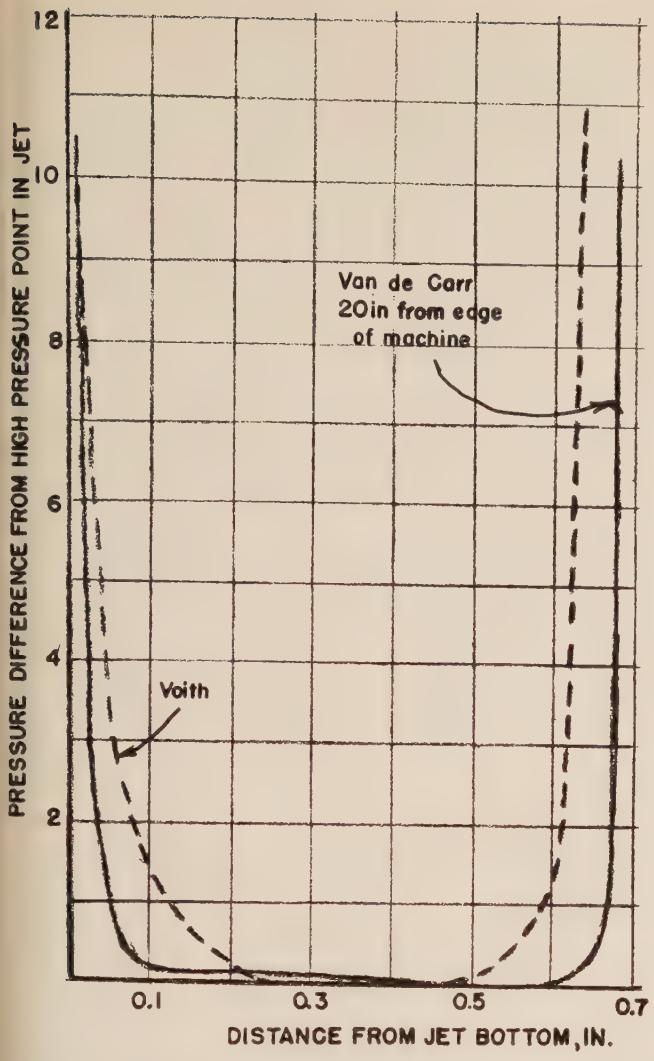


Fig. 1. Comparison of pressure profiles—Voith and Van de Carr slices (for clarity a Voith Slice of narrower opening has been shown)

overflow stock and the sheet the stock concentration reaches a maximum. Considering also that the stock velocity is tangential to the mold surface, and that the slope of the mold surface is such that the sheet tends to lie on it, conditions are very favorable for raising a portion of the highly concentrated stock with the emerging sheet.

We have observed on a uniflow vat, that the sheet is formed in two distinct layers which can be relatively easily separated while still in the wet state.

Similar observations have been mentioned by Duncan S. Brown in April *Tappi*, 1954. It appears that a higher proportion of short fibers facilitates the separation, but we do not doubt that the mechanism of formation is independent of the raw material used.

As one might suspect the formation of the second layer is very poor. Local disturbances in the flow round the vat circle give a varying degree of mixing between the main stock stream and that close to the sheet surface, and because of high concentration the stock becomes flocculated. The result is a floccy sheet with uneven substance. We would expect from the author's work that the second layer would have a higher than average long fiber content.

In the contraflow vat the wire side of the sheet is probably formed from the long fibered stock rejected by the formed sheet a moment before. The top would then be comprised mainly of short fibers.

No second distinctive layer would be lifted because at the point of separation the stock consistency is a minimum.

MODERATOR LOGAN: I am now throwing this meeting open to anyone who wants to ask any pertinent questions on these papers or who wants to make any comments thereon.

W. T. BENNETT: I would like to suggest, if possible, that there be a little time for Mr. Marden to show his slides on the pressure velocity gradients in jets. I believe that it would be of considerable interest to the group.

CHAPMAN: I have two questions here on fiber alignment and they are very similar. One is from R. N. Griesheimer of The Mead Corp. and is as follows: "Dilute suspensions of bentonite sols, in stream flow, show birefringence, primarily because of an alignment phenomenon. How is this observation to be compromised with the statement that fiber distribution is isotropic in a streaming fiber suspension? That is, if tiny bentonite particles will, why won't fibers?"

VAN DEN AKKER: I don't think that a compromise is necessary. Now, although a sphere rotates with uniform angular velocity equal to one half the velocity gradient, as pointed out by Mr. Mason, a linear object rotates with highly variable speed. It rotates with a maximum speed when it is perpendicular to the lines of flow and with zero speed (for zero time) when it is parallel to the lines of flow. The time that the linear particle spends with orientation nearly parallel to the lines of flow is much greater than when it is nearly perpendicular to the lines of flow, so that the statistical average places the particle more often nearly parallel to the screen than at right angles to it. In the flow of a fiber slurry such "statistical alignment" is absent because of agglomeration and smallness of velocity gradient. I hope that I have made that clear.

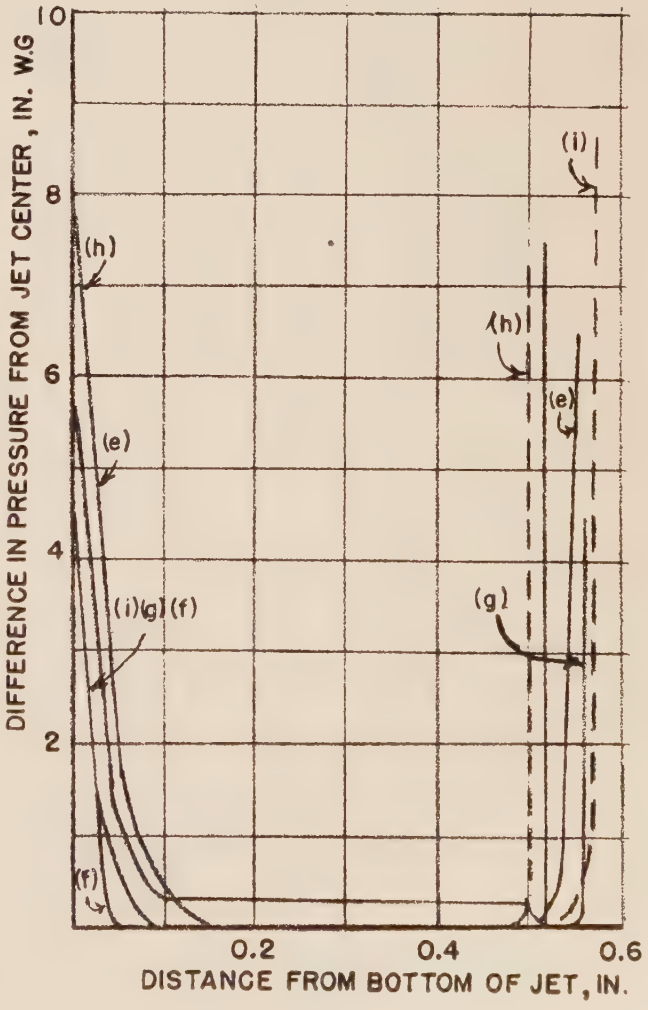


Fig. 2

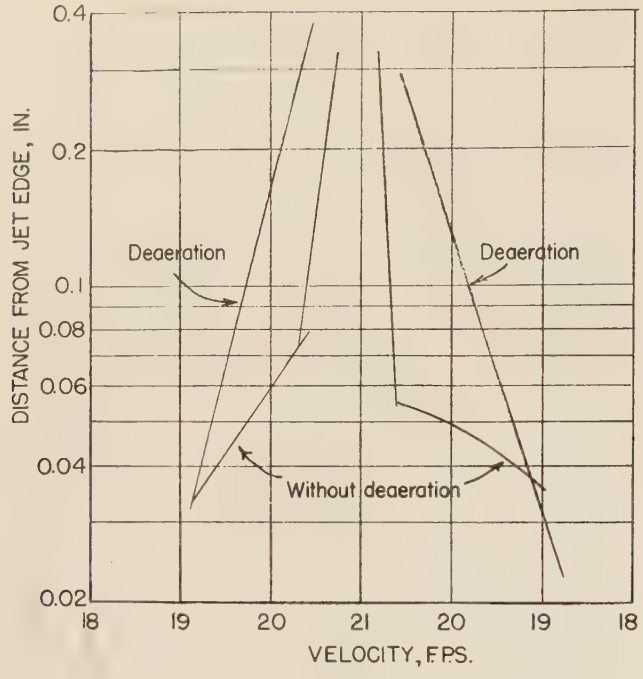


Fig. 3. Comparison of boundary layer conditions with and without deaeration of water

MODERATOR LOGAN: It is obvious that we will not be able to answer all of the questions that have been submitted. However, there is provision for answer by the authors in the recorded script and any unanswered questions will be passed on to the authors for reply in writing if they so desire.

Possibly I should follow up on Mr. Bennett's suggestion that there are some slides and comments that Mr. Mardon would like to make.

MARDON: Mr. van der Meer's Fig. 4 shows the pressure distribution across the slice jet. Figure 1 shows similar material obtained by G. Gavelin and myself. For this, impact tubes were used in the slice jet, with opening of 3 by 1 mm. and traversable on a screw thread through the thickness of the jet. Typical profiles for Voith-type and Van der Carr-type lips are shown. Figure 2 shows a part of a family of curves for an average to poor machine. The wide variations on lip openings are compensations by the papermaker for conditions in the body of the box prior to the slice. On a really good machine these curves should all be the same shape and should show approximately the same opening.

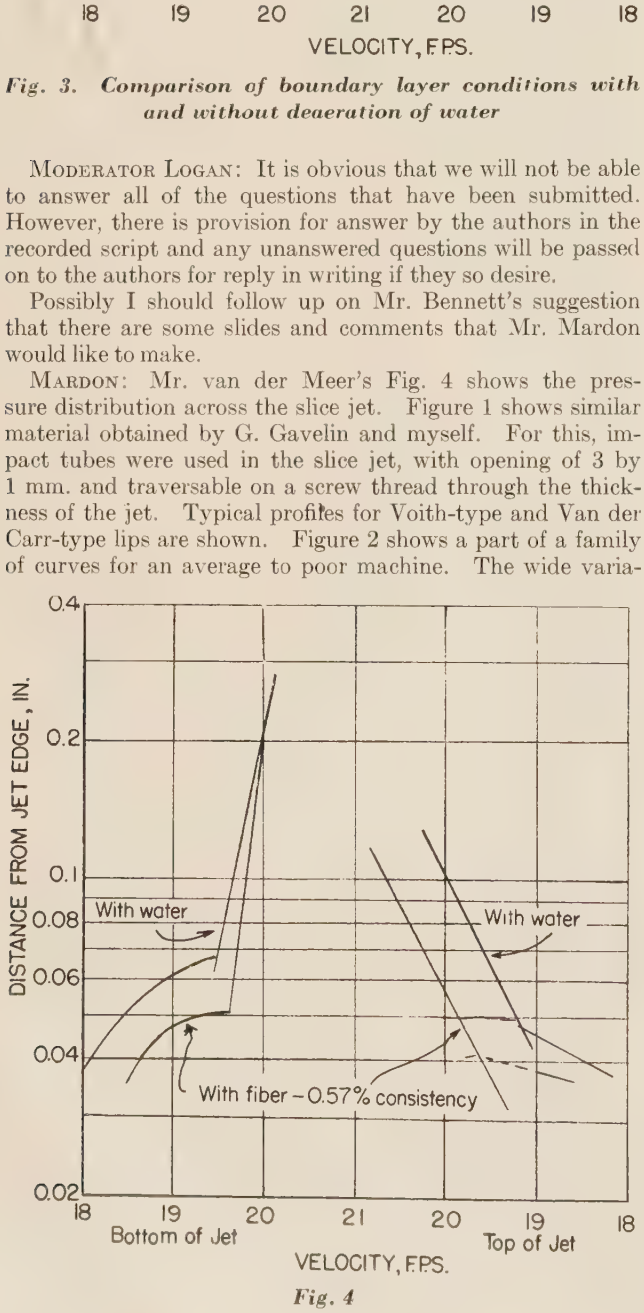


Fig. 4

Figure 3 shows a different type of plot. The vertical axis is a log plot of distance from the slice lip. The horizontal plot is speed of the jet. The left-hand side of Figs. 3 and 4 has the data for the bottom of the jet, the right-hand side for the top of the jet.

When the jet contains water (i.e., no fiber) without deaeration a break in the curve is obtained; this break represents, we believe, a transition in the flow characteristics. When the water has been deaerated using the Deculator, this break can no longer be detected; it is presumably still there but cannot be found by the apparatus, since it is too near the slice lip.

Figure 4 shows a similar plot for headbox running normally with water, and with fiber at 0.57%. It can be observed that the break point on the curve is pushed nearer the wall by the pressure of the fibers, suggesting that this boundary is more disturbed.

The above were made using the differential manometer to measure the pressure.

Figures 5, 6, and 7 show the types of plot obtained using pressure transducers on the Pitot tubes. These are attached to amplifiers and recorders capable of recording 100 cycles per sec. The finer, more jagged plot is that from the more sensitive gage we used, which was backed off with air pressure to take the full load. The time axis is either one large square equals 1 sec. or one large square equals 0.1 sec. The vertical axis is approximately six small squares equal to 5 in. for the low sensitive gage.

Figure 5 shows a plot with the tube in the center of the jet, the box containing only water but at the operating level. The chart is at higher speed. Figure 6 shows a plot for the box operating at high level with fiber. Figure 7 shows the plot when the level was lowered and stock was not passing over the single baffle—the increase in stability is evident.

The above additional experimental work has been shown as amplification of Mr. Van der Meer's paper. The plots with the strain gage Pitot tube arrangement are shown in amplification of the suggestion in Mr. Van den Akker's paper. These results will be presented in detail and discussed at a later date.

We gratefully acknowledge the help of G. Rickwood of the National Research Council in the construction and initial use of the strain gage amplifier.

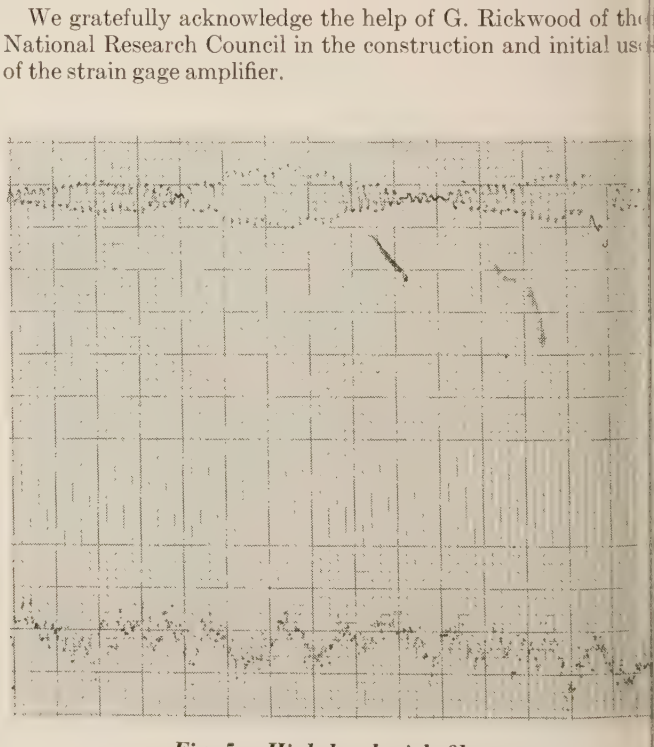


Fig. 5. High level with fiber

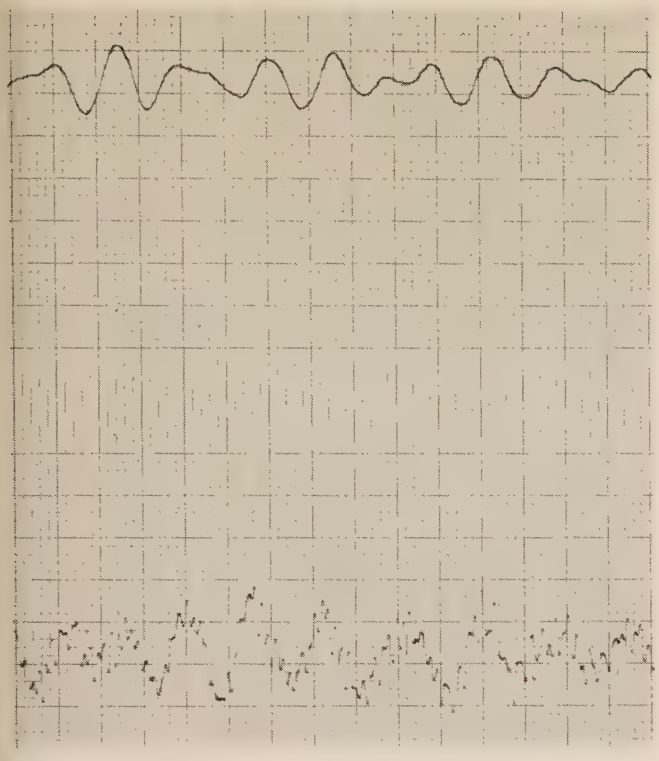


Fig. 6. No fiber, high level

WRIST: My question is in connection with turbulence. When you are measuring turbulence in air, we all know there are proved instruments available, but when you come to liquids, so far the application of the hot wire anemometer has not much success.

The only case of one being used that I heard of, which is approaching the turbulence range, is one developed by the British Hydraulic Research Association, and they tell me, disappointingly, that the response to that is 2 sec. You can't measure turbulence with response of 2 seconds.

The suggestion is made about the use of Pitot tubes, and Mr. Mardon tried using them with pressure transducers.

The transducers have ample frequency response. You can get frequency response up to 3000 cycles a sec. The difficulty is attaching a Pitot tube onto them. If you use a small Pitot tube, then the viscous forces in the tube reduce sensitivity down to a few cycles per second.

If you use a large diameter Pitot tube, you reduce the effect of viscous damping but you can't make a small scale turbulence.

This problem is still to be solved, and I think in studying the work which Mr. Mardon has shown us, that you have to bear in mind that some of the frequencies which you see may be functions of the Pitot tube itself, and not of the turbulence jet.

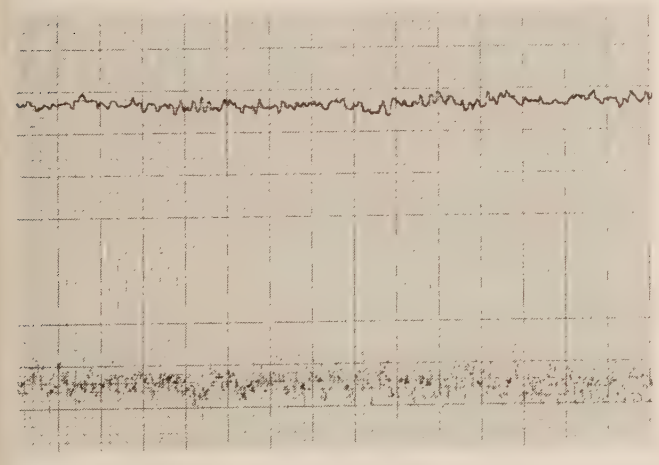


Fig. 7. Low level with stock

Perhaps Mr. Van den Akker has some additional information which I have not been able to get in connection with measuring turbulence in water or any other liquid.

MARDON: First of all, about the hot wire anemometer. Hubbard has a dissertation on this; and we have Mr. Laursen of the Iowa Institute of Hydraulic Research in the audience, who can give us a treatise on his response on the hot wire anemometers.

Secondly, you will notice when discussing the results I put up I very carefully abstained from indicating that they were in fact measuring the differentiation between the turbulent diameter regions, and particularly when you have to use a Pitot tube orifice much bigger than we like. Our orifice, for the record, is actually 3 ml. in the width direction of the paper machine and a millimeter thick. And even an orifice like that, when you are using it with fibers, clogs up very easily. And for our fiber agglomerates we have a somewhat larger force.

EMMETT M. LAURSEN (Iowa Institute of Hydraulic Research): This last question of the hot wire anemometer—many places have been working on the problem of measuring turbulence in water for quite a while—M.I.T., Iowa, D.T.M.B., and there are a few others.

M.I.T. has an instrument that they, as I recall, will measure fluctuations in the longitudinal direction only. Iowa, under Hubbard, developed a somewhat similar instrument. And now Hubbard thinks he has pretty well licked most of the "bugs" in the hot wire anemometer for use in water.

One of the biggest problems was dirt and gas bubbles forming on the wire that weren't washed off. By inclining the wire at 45° and using larger wires, low heat, and somewhat different electronic gear he has developed a relatively stable, sensitive instrument to the response. A desired sensitivity can be designed into the instrument, that is well over 400 cycles per sec. Furthermore by using two wires you can measure double correlations; or, with more wires, triple and quadruple correlations.

I think the furthest advance that has been made in hot wire anemometry in water is this latest work of Hubbard.

In addition, Hubbard has worked on the electronic arrangement, and using a constant temperature system has reduced the size of all those boxes that used to be up on the wall to a piece about this size (indicating approximately 3 by 2 ft.); and with that you can get a root-mean-square, a differentiating circuit for scale, and correlations directly.

While I am on my feet I would like to make a few other comments.

First, I should make it clear I am not a papermaker. I am just an observer from a hydraulic laboratory. But so many of your hydraulic problems are strikingly similar to hydraulic problems in other areas.

For instance, the point that has been brought up in connection with Mr. Van den Akker's paper, the friction of stock being less, or the loss being less with a concentration of stock, is very similar to one we have with suspended sediment where we have suspensions of clay or silica (silt and fine sand) of size, up to from less than one, up to 5 and 10% by weight.

Some claims have been made that the resistance is less with a suspended load. However, I believe that in all such cases the surface conditions have not been considered. There has not been a measurement of the surface condition and when you look at the experimental setup considered, it appears possible that the surface changes from rough to smooth.

Your paper stock fine particles filling up roughness protuberances may account for some of this apparent change in frictional resistance that is ascribed to an apparent change in viscosity.

Another condition we have noted in our suspended sedi-

ment work—we get definite changes in concentration that are fairly large scale—the same effect you can see in the river in flood time. Actually, our problem was the question of how big a sample we needed to get a good statistical average.

I know that in the field measurements by the U. S. Geological Survey with their sediments, they always take two samples, and sometimes one taken right after another one can be 10 times as large.

Perhaps this variation could occur in paper stocks to a less degree, but even then might be important in your problem.

And then there are all the cases of flow expansion. At Iowa we had an extensive series of tests of fire monitors and nozzles, in which the old style nozzle or monitor was a rather ram's horn device that comes up like this (demonstrating), so it can swivel down here and swivel up here to direct a large fire stream, $1^1/_2$ or even 3 in. in diameter.

We cut down the large scale turbulence in the monitor by having miter bends, and small vanes in the bends. This improved the fire stream, the carry, and the concentration a great deal.

The old-fashioned nozzles were made with a conical section followed by a short tangent, so it would be like this (demonstrating). At those sharp breaks there was separation and turbulence. After studying a series of nozzles, the best one was a curve tangent at the barrel and contracting to an opening larger than the first jet diameter leaving the rest of the jet to form by itself. Again it increased the carry and concentration of the jet.

This is a problem in many respects similar to yours.

Another case was a power canal where the flow was decelerated from an open cut in rock of small section to an earth canal of large section. A short transition was desired, and there was a problem of scour downstream.

Reverse curve vanes with an angle of flow of 7° between the two vanes solved that problem.

Incidentally, Mr. van der Meer's figure of 12° for the flare angle rather surprised me. In most of our work, and I think most of the work most people have done, 7° is considered about the correct one. However, the angle depends on the area ratio, on the Reynolds number, and the turbulence.

But it is really surprising, how some of the many things shown here today, some very specific, some more general —have such definite similarity to the problems in all other fields of hydraulics.

Moderator Logan: Thank you very much, Mr. Laursen. It was most kind of you to come and join our deliberations today, and we certainly appreciate your remarks.

The meeting recessed at 5:30 o'clock.

WEDNESDAY, SEPT. 22, 1954

The second panel discussion and question period convened at 3 p.m., W. Boyd Campbell presiding.

Moderator Campbell: On this side (indicating his left), we have the five people who have presented papers with various kinds of new ideas today. On this side (indicating his right), we have the Devil's Advocates, who will try to present the case for conservatism, or possibly they may be converted and they will be only damning with faint praise.

In case you don't know who they are I will name them from right to left. These fellows you know, of course (indicating those who presented their papers). First is Peter Wrist, Quebec North Shore; C. A. Lee, of Kimberly-Clark; Charles Sankey of Ontario Paper; W. J. Foote, of Consolidated Water Power and Paper; and P. S. Blickensderfer, of Champion Paper & Fibre Co.

There have been a few questions, but first, before we take up the questions I am going to ask Mr. Wrist to make his comments on the paper by Mr. Whitney.

Wrist: I think that I should start out by complimenting the two authors of the paper for the very fine way in which they set out the experimental work and more particularly for the way in which they have pointed out the limitations of the experimental techniques and of the theoretical side.

I think that in the discussion we should try to find out how this idea of an average specific resistance is going to be useful in papermaking.

There has been quite a lot of scorn poured on the freeness test. These tests serve some purpose but there are some severe limitations, and I think that this is one of the first attempts to place a test for evaluating pulp on a scientific basis.

There are two very attractive scientific concepts involved in the idea of specific resistance—that of specific surface and specific volume of pulp.

If we can put pulp evaluation on the terms of some concept like that, I think we probably have gone a long way to providing some ideas for machine design.

Now, before we go too far along the way, I think we have always to bear in mind that the evaluation of these two concepts of surface and volume from experimental data depends on the use of the Kozeny-Carman equation. In the other fields of filtration, this equation is falling into some disrepute, and there were recently two attempts to introduce new ideas into filtration theory.

One very recently has introduced an idea of dispersivity. This is another concept that we have to take into account besides porosity and permeability.

Very roughly, the idea is that if you have a filter pad and have some liquid going through it and you put in a small drop of ink at the top surface, then that drop of ink won't come out the same size on the underneath. It will be diffused going through the pad and that has got to be taken into account in the mathematical expressions.

The theory is not fully developed yet but at least the basic equations are a little more complicated than the Kozeny-Carman equation.

The authors have born in mind throughout their work the possible limitation of the Kozeny-Carman equation and I think that provided those limitations are always borne in mind for practical papermaking that there is something to be gained from the idea of average specific resistance on the more practical side of papermaking.

Now, on the more practical side, how do we use this average specific resistance on the paper machine and also, does the average specific resistance that we calculate in the laboratory agree with the resistance on the wire?

The bridge between the laboratory and the machine is coming from the two ends. At the Institute here they are doing it from the laboratory and others are approaching it from the machine. As yet the bridge is not complete.

I think that in the discussion we can point out some of the remaining facts which have to be cleared up between those two approaches and if we can do that, then that will be very useful.

Mr. Bennett was unable to give in his paper the full details of the approach from the machine point of view, of the average specific resistance but some figures which have been obtained both at Kenley and by the Wiggins-Teape organization do show at least, that the orders of magnitude of resistance calculated from machine draining and that from the pulp in the laboratory are very close.

Perhaps then, in the discussion, we can try and bridge over the gap between the two aspects.

One of the things which we have to consider is the possible effect of the fines in the sheet, and the authors in discussing this paper with me mentioned that they had taken some stock from the headbox and made a specific resistance on it and that then they had taken paper from the couch, disintegrated it and then made a determination on that. They found there is a difference between the two.

Obviously then, in a laboratory test which will evaluate the way the pulp will behave on a machine, we have to take the

fines into consideration. Perhaps it will vary from machine to machine. Do we require then some test which we can apply to evaluate the pulp *per se* and then another test or some variation of the first test which we can then use to say how the particular pulp will behave on a particular machine?

With those few remarks I think that I will put the discussion to the house.

MODERATOR CAMPBELL: Has anyone any comments to make from the floor on this point?

J. D'A. CLARK: I would like to say that I enjoyed the paper very much today. However, there are one or two points that I would like to bring up which might be of some interest.

All kidding aside, the fact that it has now been found that the Schopper-Riegler freeness tester doesn't correlate with specific surface in accordance with the Kozeny-Carman equation, gives me much satisfaction because I understood that was the last reason as to why the Schopper-Riegler apparatus might have some value.

This apparent specific surface as determined by the Kozeny-Carman equation has an objection that if you plot it against beating time, you get an inverse curve. We know that as far as strength development is concerned that with wetting the curve rises rapidly and then comes around this way (indicating); whereas, unless you have obtained the reversal of Mr. Mason's result, the specific surface goes this way, the other way, and that it correlates with the freeness.

I don't think that it is a very apparent specific surface to which you are referring. For that reason I will admit the invalidity of the silvering method but I think also, because of the shape of that curve, that the specific surface, as measured by the Kozeny-Carman equation, is highly suspect.

The one difficulty I see with respect to trying to measure and correlate laboratory measurements of stock on the paper machine is the fact that Underhay brought out, and others hinted at today, the washing effect of the table rolls. Here we have stock coming from the headbox, replete with a lot of extra fines; and as it goes down the wire the tube rolls are throwing water at high speed into the stock and washing out the fines. That is a very fine piece of work that Underhay did; showing the washing effect is rather thorough. Now, how on earth can we really determine ahead of time, without simulating that effect?

I was extremely interested in the paper by Mr. Bennett. It's a very good piece of work, and I want to suggest to him that maybe one of the factors that would correlate best with the drainage rate on the wire would be the apparent density of the stock as determined in accordance with established methods. I have advocated that test in place of the freeness test.

As we heard today, the freeness test is nothing but a measure of fines, of debris, and they are of very little importance. I'll tell you why they are of very little import—because when they are circulated in the machine headbox and have been drained through the wire, you have pinholes formed, and those fines go through the pinholes and come around again. It is not true, as the assumption has been implicitly made, that because you get the same amount of fines out as you put in, plus a little loss in the white water, it is valid to measure the quality of the stock with the fines.

I say—no; that's nonsense, because we know that in accordance with measurements on the permeability of the wet sheet, that if the fines really were effective it would be most impermeable.

We must assume—and I think it is true, as all of you folk know who make fine paper—that you get pinholes formed on the machine, and those pinholes permit the fines to pour through. What are we left with?

I suggest, and I can see from, for example, that last paper, where there was a graph plotting sheet dryness against beating time, that there was a straight-line relationship. And I noticed you had a logarithmic relationship of beating time.

I have said in the past, and the Australians have confirmed this very accurately, that if you plot the logarithm of the beating time, or the logarithm of the input against the sheet density as determined by the TAPPI or British Standard method, you get a perfectly straight line, not a curved line—but a perfectly straight line, up to a value of at least over one. And furthermore, it would appear that line is a parallel line for all different kinds of pulps, more or less. That is a very valuable find, gentlemen, because the slope of that line appears on the beater rather than on the pulp itself.

I don't know quite why that is, but we will talk about that another day.

This is the point I want to make: unbeaten straw pulp has a density of around 0.7; groundwood pulp has a density of about 4.5; a sulphite pulp, about 5.5. If you beat the sulphite pulp up to 0.7, I know from previous experience that you will find that beaten sulphite pulp will be very similar to the unbeaten pulp.

And I believe each one of your paper machines has a certain range of density that it can handle, depending on whether it is built to handle glassine or newsprint. And no matter what the pulp is, if you blend it or beat it, so that its final density, sheet density, as determined by the British Standard method, it will work properly on the wire, if it is such.

MODERATOR CAMPBELL: I think probably Mr. Whitney would like to say a few words.

ROY P. WHITNEY (Institute of Paper Chemistry, Appleton, Wis.): First of all, I would like to thank Mr. Wrist for his remarks which are gratifying and certainly indicate that he has done some work on this paper. He very adroitly pointed out some of the difficulties involved in this work, particularly with respect to the Kozeny-Carman equation, or any other equation which one might choose, in that obviously there are deficiencies in the theories.

Those of you who are familiar with the development of the Kozeny-Carman equation will know that the assumed physical basis on which it is developed is too simplified. But our position—and I am sure Mr. Wrist understands this—is that it seems to be the best relationship which is presently available for trying to break down the rather gross concept of the filtration resistance into something which may not be fundamental, but at least is not quite so gross and empirical as the filtration resistance. So, we have used it, for want of something better, as I tried to indicate in my presentation this morning. We have tried to check the equation independently where possible, and unfortunately that is difficult to do.

One of the obvious points of vulnerability of the equation is in the so-called Kozeny constant which I rather arbitrarily brushed off by saying we used the value of 5.55, which was determined by others for fibrous materials, and may or may not be a good value. The fact that we were able to check the specific surfaces of the unbeaten pulps was comforting in that it indicated the value was not too far wrong.

There has been much more indication in our work that the specific surfaces were more valid, shall I say, than in the case of the effective specific volumes. Now, this is a rather peculiar figure, the specific volume, in that it doesn't correlate with the reciprocal of the density of cellulose, either under wet or dry conditions, and I think is actually better called the hydrodynamic specific volume—that is, the volume which is denied to flow by the presence of the fibers and may in fact include water, which is just mechanically held but which does deny flow.

Our work on moisture content of fibrous pads during filtration, in which I indicated that we have been able to check experimental and calculated values, is just about the first positive thing that we have found to indicate that perhaps this value, too, (the effective specific volume) is a reasonable value.

We frankly do not say this is complete; we have only scratched the surface of trying to understand the significance

of the effective specific volume. Mr. Mason has done much more than we have, as a matter of fact, in trying to elucidate the meaning of this particular term.

With respect to Mr. Clark's comments, I might say, Mr. Clark, I think you are perhaps a little impatient. This has been a long road, and there is a great deal more to be done. I would agree with you that the specific surface which we measure may not be the specific surface which is effective in determining the strength of the sheet. Obviously, any technique based on permeability or filtration can measure only the specific surface which is effective in that particular situation. I think that is true of the silvering technique; and it may or may not be that the situation is the same in the silvering technique and in the filtration work.

There are too—and you are just as well aware of this as I am —other factors which affect the strength of the sheet, as well as specific surface, and some of them are apparently not operative in a dilute slurry.

I think—in fact I know—that one will find a general correlation between filtration resistance and strength properties of dry sheets, just as one finds such a correlation with freeness. I am personally convinced that neither freeness nor any other property determined in a dilute aqueous suspension will determine, effectively, the strength properties of a sheet of paper. I might surprise you by telling you that we feel there is some utility to freeness. We have tried to show that it is not a reliable index of drainage rate under widely varying conditions. But I think, particularly in a mill which is making one grade of paper day in and day out, the experience which has been built up on the basis of freeness tests is very valuable, and I doubt that it will be thrown overboard in favor of anything which we may have said today.

Actually the freeness test suffers from a number of faults. The principal two are the fact that it operates at a head which is much lower than that existing on most machines today and that it operates under conditions of falling head. The head is not constant. There is some indication in some of our work that while we would expect from the compressibility, that during the freeness test when the head is falling, the mat should be expanding—not compressing but expanding—we have some data which indicate this does not take place. Again it is a matter of kinetics as well as equilibrium situation.

We feel that freeness is probably here to stay. We feel, though, that out of the work which we have been trying to do, and the very interesting work which has been done in England, some new concepts are developing which we hope one day will be useful.

We hope, as Mr. Wrist expressed the hope, that we are going to meet in the middle somewhere, inasmuch as we chose quite a different approach from that which has been chosen in England.

Steenberg: Mr. Chairman, in the paper I gave yesterday on behalf of our group, we have also reported some filtration experiments; and we have a different technique.

We use the probe described yesterday. It is put down into a sump, and a sheet is formed upside down, which means we always form it from a stock of the same composition.

In the theory we assume that the quantity of fiber fixed to that wire is proportionate to the volume drained, which is true when there is no rate of flow of the stock relative to the wire. The agreement with the theory is remarkably fine. We have much more data than what are shown here, and the agreement is remarkable.

But now the difficult thing is that if you have a flow of stock relative to the wire, you still find the theory to hold. But then there is no proportionality between the quantity of fibers fixed to the wire and the volume drained, which is assumed in calculating the formula. There must be something wrong here. I was very surprised that nobody commented about it, and perhaps it is simply that it is some confusing observation which we can't explain today.

I think it would be very interesting to have this commented upon, because it is a sort of different approach, a different experimental setup from most of the other experiments that have been done in this field.

Nissan: I want to draw attention to work by Barkas and his colleagues—Hallan, Christienson—as he is not here, which I think is characteristically meticulous, and the experiments are rather beautiful. I think the term applies to all of Barkas' work.

One point is that it applies to the paper by Mr. Nordman. Mr. Nordman talks of the elastic characteristics of the wet web. The surface expands and the capillaries expand and the air can flow. Barkas has found an important point and that is a hysteresis effect—an important fact. He has found hysteresis in the compressibility on the first cycle. This hysteresis with paper and pulp seems to plague all experiments whatever they are. Things happen in the first cycle which do not seem to happen afterward.

I bring this point to the attention of Mr. Whitney because in this method of measurement the sheet is made first, then it is allowed to expand, and then, if I understand it correctly, compressibility is measured.

You will remember, gentlemen, as I do, that the equation for the curve obtained had a constant in it and I am wondering whether this, in effect, does not cover sins of omission and commission due to the hysteresis in the first cycle?

I think that a correlation between the work of Barkas and these papers will be very useful.

There is one other thing and that is that Mr. Barkus has also found a particular point on your curves—a kink in the curve when air just begins to penetrate the sheet. This may be significant in today's papers.

I do think that in all of our discussions of pulp characteristics and drainage we should take great note of the work of Barkas.

There is one more point which I discussed informally with Mr. Whitney this morning and it is something that has puzzled me for years.

You know, water flowing into small pores seems to behave in a peculiar manner. For instance, if you take a glass filter and push water through it, when you come to study the characteristic of the permeability obtained, you find it is not completely explained by the viscous traction, by the viscosity factor of water. For instance, you get different permeability at higher temperatures than at lower temperatures with distilled water and we guessed that it might be due to surface tension effects. Therefore, we tried to reproduce the effects by changing the surface tension by adding salt, alcohol, or by some other means, and we found that you could correlate the results, taking surface tension into account.

However, gentlemen, surface tension as we measure it, is between air and water—presumably it is correlated to the interfacial tension of glass to water.

However, how can interfacial tension affect the flow? I do not know.

The second thing, it looks as if the boundary layer, as in Mason's finding, confirmed today by Mr. Whitney, that the volume of liquid which is not available to flow is of large magnitude, measured in Angstrom units where molecular forces apply. Now, what kind of forces apply at such tremendous distances is something that I do not know.

I would like somebody to enlighten me on that since, particularly if you take small particles like a single fiber and allow it to sediment, you find no such force. You find that the specific volume, for instance, is not unlike what you get from other factors.

Therefore, the things that happen in the small capillaries are peculiar and I would like to know if Mr. Whitney has some comment to make on them as they must affect papermaking.

WHITNEY: I can answer the question as to what sort of forces are involved here easily. The answer is that I do not know either. We, too, have been bothered by the large amount of water which apparently is immobilized. As Mason and many of you know, there has been some permeability work in the literature, where the ordinary specific volumes were used and where extreme difficulties were run into thereby. I think that it is fairly well established that in such work we must rely on the hydrodynamic specific volume. We certainly must admit to a great deal of ignorance regarding it and as to just why the water is immobilized as it is.

Commenting on Mr. Nissan's earlier remarks about the initial upset in compressibility measurements—he is quite correct. There is such a thing and we are aware of it. As I tried to point out this morning, our compressibility measurements suffer very definitely from the fact that they are made after the lapse of a considerable period of time. There again all that I can say is that it is something that is recognized and where we hope to get into the more interesting range of what happens immediately.

Incidentally, I did not point out this morning for lack of time that one other advantage of the constant rate technique is that one gets off to an immediate start, as the data are taken immediately from the start of the filtration whereas in the constant pressure experiments almost invariably there is an initial period of upset before one can adjust the pressure differential to the desired value. The fundamental relations must be integrated over a period which does not include the initial condition, which is again rather unfortunate.

While I am talking, I might comment briefly on Mr. Steenberg's remarks. We read his paper with great interest, because some of it was so closely related to ours. As he pointed out, the approach and the mathematical developments were different but we convinced ourselves that they are equivalent and we found a great deal of agreement between the conclusions that they reached in their report in relation to our own. It is interesting, I think, that several of us in different parts of the world are working along the same lines and at least are not in too great disagreement.

WRIST: There is one aspect which has been touched upon by Mr. Whitney and Mr. Nissan and that is the rheology of the web. In the measurement that you gave us in your paper you did say that with a constant pressure measurement you found there was a time effect which was absent in the constant rate effect and you attribute this to the absence of web due to the greater rate of filtration.

When we think of high speed paper machines, we realize, that there we have a pulse of filtration of very short duration each time the web goes over the roll. A very high suction is applied for a very short time, maybe of the order of $^1/_{700}$ of a second and this occurs perhaps 20 times going down the table. Obviously the rheological properties of the web during this very short application of pressure are going to greatly affect the drainage. Perhaps there are some rheologists here who would like to comment on this aspect of the drainage—the very short duration of application of pressure.

MR. GALLAY: A portion of the topics with which I shall be dealing tomorrow morning will be concerned with the rheology of the wet webs but it will be rheology in tension and not in compression. We have some work under way which will deal with rheology in compression but it is so early in the game that I would rather say nothing about it.

However, as you will see tomorrow morning, we did make a considerable number of measurements on the caliper of the wet webs containing different percentages of solids and those measurements were made under a series of increasing loads, following which we extrapolated back to zero load in order to get close to a true thickness value—as close to one as we could. Most of the load-thickness relationships were straight and a few had a slight curvature.

Now, we were faced with the same problem of course, as that referred to. Knowing, that there was hysteresis in this rheological system, we chose to take those values which included the recoverable creep so that we obtained what were really minimum thickness values rather than those one would obtain by attempting to make such measurements at another point in the load-elongation cycle in compression.

FOOTE: In view of the data presented this morning I was wondering if you have any information on the per cent of water that is carried around the table roll as it enters the nip and, secondly, does your equation take that into consideration?

WHITNEY: Our English and Canadian friends are much better on that than I for they have done more work on it. We think that the amount of water that recirculates around the table roll and comes back to the sheet is very much a function of the individual machine.

Now, with regard to your second question, as to whether the formula takes such a thing into effect, the answer is that it does not. That is a very simple formula and it fails to take into account quite a few things which we know must happen on a paper machine table.

It is designed simply to get the metric picture shown on that little sketch.

INGMANSON: There are only a few minor comments in answer to a point raised by Mr. Clark when he commented on the peculiar shape of the curve you get when you plot specific surfaces as a function of the strength properties of the sheet.

From the work that I have seen in the literature in that regard, the specific surfaces as determined by permeability or silvering techniques are always done on the whole pulp, which includes all of the fines, whereas the handsheets lose a considerable amount of fines of very high specific surface. The point I wish to make here is that it would be better to determine the specific surface as the *same* pulp as that in the handsheets.

Now, with regard to the anomaly that Mr. Steenberg brought up, of the apparent applicability of the filtration equation, this brings to mind another phenomenon that can be found in the analysis of freeness testers or drainage testers.

For instance, in the Williams drainage tester, if you make the assumption that the cellulose mat is incompressible and if you obtain time-volume data as the sheet forms in the Williams tester, then application of filtration theory shows that the assumption that the mat is incompressible is a perfectly valid assumption. This is remarkable especially when you are starting with what you know is a false assumption. Mr. Campbell noted in 1947 that a similar assumption was made in preparing the consistency and temperature corrections for the Canadian Standard freeness tester, and apparently it held quite well.

MODERATOR CAMPBELL: Thank you. I think that we had better keep on traveling or we will not get a chance to discuss the other papers.

Mr. Wrist has quite a number of written questions. Some of them have been covered through the discussion and possibly some of them haven't. Will you bring those forward please?

WRIST: The majority of them are asking questions similar to this: "How does the filtration resistance correlate with the Williams freeness test?"

There are other ones asking what is the relationship between average filtration resistance and filtration resistance on a normal paper machine?

I think that most of them have been covered by your remarks in reply to Mr. Clark about the general properties of these testers.

Now, there is one question which doesn't quite fall into that line. This one is from Richard Roberts.

"Figure 9 shows the filtration resistance increases with beating. Over the beating curve of any given pulp, do the filtration resistances of various fiber length fractions obtain-

able from that pulp increase at similar rates?" That is the essence of the question. Do you have any comment on that?

WHITNEY: I believe that I know what he is driving at and I further believe that I can answer that only in very general terms because we have done a very limited amount of work on filtration resistances of fractions of the pulp.

I would be inclined to agree that as one beats the pulp it appears that what happens is that one makes fines and, of course, there are other things, like Clark's fibrillae, but it appears that the increase in the specific surface is very largely due to the smaller individuals which form as a result of the beating.

One can fractionate a pulp, take another sample, beat it, and fractionate it again and find that both the freeness and drainage characteristics of the long fractions have not changed much. There has been a change in the relative amounts of the fractions.

We have done very little work and that is about as far as I can go.

SHOUMATOFF (submitted in writing after the symposium): The filtration study by Ingmanson and Whitney has presented us with a carefully developed theoretical background and highly competent experimental work resulting in a series of curves showing high precision and regularity. The development by this means of the concept of specific resistance as an important property of pulp from the papermaking point of view is highly convincing.

At this time, rather than discuss details of their work, I would like to indicate briefly how the approach differs from some of the concepts which I had formed in my own mind as a result of an attempt at a more generalized type of permeability study not specifically concerned with fibers (*Tappi*, April, 1953).

As indicated by Ingmanson and Whitney, their filtration equation is limited to laminar flow and also breaks down for high porosities, somewhere around 0.8. This apparently limits the direct applicability of their equation to the mechanics of drainage on the actual paper machine. This was suggested by the necessarily much less precise operating data in Bennett's paper showing that temperature had relatively little effect on drainage in the first part of the table. Apparently conditions of high porosity and turbulence do exist in the initial stages of sheet formation so that it might be of value to extend the laboratory conditions to include phenomena in this range. This would require a less limited filtration equation.

Such an equation was used in my 1953 study, which included a two-term fraction factor to allow for both viscous and inertia forces using a simple porosity function. This is a simple exponential and although it may be less accurate and less linear in the low porosity range than the Kozeny function, it does have the advantage of having no limit as to high porosity. The conclusion that resistance is proportional inversely to the 4.3 power of porosity was in approximate agreement with the results of many other workers. Incidentally, with a function of this type, there would be no difficulty in integration, such as was found with the Kozeny function. Some insight into the arithmetic and the range of proportionality of the two functions is shown by the following table:

Comparison of Porosity Functions

Porosity E	*Kozeny function* $(1 - E)^2/E^3$	*Empirical function,* $E^{-4.3}$
1.0	0	1
0.9	0.0137	1.57
0.8	0.078	2.61
0.7	0.262	4.65
0.6	0.74	9.1
0.5	2.0	20
0.4	5.6	52
0.3	18.1	175

Another aspect of the Ingmanson and Whitney study is their use of specific surface as a variable affecting drainage independent of compressibility. Actually as the fibers become compressed, a larger proportion of the surface becomes normal to the general direction of flow and exerts less resistance. In other words, the shape factor changes with compressibility and a method of calculating this effect was included in the 1953 study. In the same paper, the influence of mixtures of particular size on drainage was critically considered, particularly for turbulent flow conditions.

A further consideration is that filtration, especially of the constant pressure type, is a transient phenomenon, while the original Kozeny equation assumes steady state. It would seem that more explicit consideration of transient effects would be warranted than by purely mathematical manipulation of a steady-state equation.

The above comments are not intended as criticisms of an excellent investigation, but merely to indicate that certain differences in viewpoint exist which may prove useful in future studies.

J. R. CURTIS (Scott Paper Co.): Your work indicated a good general relationship between specific filtration resistance and freeness over the normal paper machine operating range. What special fiber or pulp properties can be detected by filtration resistance that cannot be by other more common tests?

WHITNEY: Our work has indicated that freeness is a very crude and rather peculiar index of filtration resistance. We feel that specific filtration resistance is a much more reliable and accurate indication of a pulp's drainage characteristics. As pointed out rather extensively in the paper, filtration resistance may be resolved into components of specific surface, specific volume, and pulp compressibility. We feel that these are important pulp properties and know of no way in which freeness values may be interpreted in terms of these or any other pulp property.

MODERATOR CAMPBELL: Before passing on to the next phase of discussion, may I just put in one point for the record?

By the Kozeny technique, both specific surface and specific volume are determined, and it is a remarkable fact that specific volume curves are very nearly the same shape as the curves showing the increase in strength with the beating. Now, just why that is so, just what that specific volume means, is a bit of a question as yet; but I think it is well to bear that in mind in thinking about the thing.

We've spent some forty minutes—or near it—on this paper. Now I suggest that we go on; and Mr. Lee will make comments and bring up the questions concerning the paper by Mr. W. E. Bennett.

C. A. LEE: First, I feel that Mr. Bennett should be congratulated on his paper, and particularly upon the objective that he enunciated with regard to why he started on a paper machine; that is, that he desired to find out what the problem and what the various variables were before entering into the laboratory work.

His method of analysis in trying to obtain the answer to how the variables applied, I felt, was very excellent. However, he pointed out a couple of items that I think he should like to elaborate.

One is the effect of temperature in the early part of the paper machine. He had indicated that at a speed and at the operating conditions of the paper machine, that temperature was not deemed to be effective in the early part of forming the sheet; and I would like to have him comment on that item.

Also, to perhaps elaborate upon the effect of speed with regard to the work that he has accomplished.

With regard to the suction at the crown of the table roll, if you were to calculate from his formula the amount of suction present at speeds in the order of 1800 to 2000 f.p.m., it would be quite high, and I doubt very much if that degree of vacuum exists.

I feel, therefore, that the work should be extended and carried into the other considerations of speed—forming board, special tube rolls, baffles, and doctors that are present in our present high-speed machine.

I might make one other comment with regard to the matter of filtration as affected by the paper machine operation and by the tests by Mr. Whitney.

It is entirely possible that a redistribution of the water in the filter-mat takes place, particularly on the paper machine between successive tube rolls and prior to the flat boxes. That is to say, the redistribution takes place, and it redistributes itself and presents itself in a more favorable condition for water removal as the sheet travels down the machine.

W. E. Bennett (British Paper and Board Industry Research Association, Kenley, Surrey, England): To deal with your first point, the effect of temperature, I did skip over this a little bit, I am afraid, and I said that temperature, from our first experiment, which I've been describing, was effective on the second half of the table, in the last two blocks of the diagram in Table III, rolls 10 to 21. There it was statistically significant. The effects, toward the wet end, in that experiment, are not significant.

There is one other point I would like to make about this regression analysis. It's a very useful technique to use in certain circumstances, because we didn't have to interfere with the running of the machine. You can take the results as they come, and they are analyzable.

Of course, there is one very basic assumption necessary to get any information out of such an analysis, and that is that the factors which you are comparing should be independent of each other; and, of course, they seldom are.

We know very well that a lot of these factors are interdependent. So, because of that, there was a certain amount of doubt in our mind as to the validity of many of these results, and it was for that reason that we did another experiment later on.

The experimental details were very much the same, but we ran this experiment with different combinations of the factors. For instance, velocities were 600, 640, and 680; as near as we could get them; and there were small fluctuations, of course, about these three points.

By doing an experiment to a factorial design, you can sort out the main effects, of the factors on drainage and also the interaction. And if anything shows up very strongly in the interactions, it will almost certainly modify the results of the analysis, if you did it the first way, by the regression technique.

The temperature effect in this third experiment, which I haven't had time to talk about, was very much stronger than it appears in here. It was significant much earlier on the table. But generally the picture is not altered. It is more effective on the drier end of the table than on the flowbox end.

And I did say that that seems to tie up with the fact that you are more likely to get the capillary type of flow at the drier end, and the orificial type at the other.

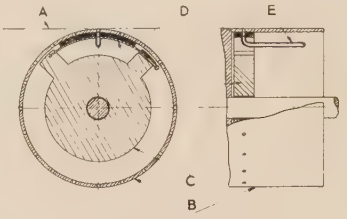
The effect of speed and these very high suctions, which go up according to the square of the velocity—I would like very much to measure them at higher speeds; but we have not been able to do it yet.

I have no reason to doubt they are there, but they may be very difficult, indeed, to measure, because on that diagram I drew this morning—it is actually one of the figures in the text—the suction is only operating for something like half an inch. During that period we have to measure 20 or 30 points, and it is very critical to find the places of maximum suction. At high speeds, the peak will be very sharp.

We have never been entirely happy about the way we were measuring the suction by having this piece of material skidding along the surface. Of course it obviously disturbed flow lines. But just before I came here, I had an interesting talk with Mr. Brauns and he suggested to me another way of doing this.

This is a way of avoiding anything on the top of the wire. In fact, although we have still done our measurements with water only, we could quite probably use pulp. Instead of having an ordinary table roll, we have a hollow one, with perforations in it, and in effect it is a sort of suction table roll.

A. Machine wire.
B. Table roll, with one ring of perforations in a recessed end.
C. Stationary block.
D. Spring-loaded,rubber, sealing strip with one hole matching ring of perforations.
E. Connection from hole to manometer.



Apparatus for measuring suction at a table roll

As you can see, looking at the table roll end on, now, here is our nip of water; and the seal is now occupying this area (indicating), and we can move this around to cover the area covered by the nip of water.

I had a letter a couple of days ago from one of my colleagues saying that they had been measuring the curves in this fashion, and they also had an artificial resistance on the top of the wire, a certain thickness of cloth.

The actual shape of the suction curve was very similar to the ones which I showed you this morning. The actual peak value is not quite the same, but there is no great discrepancy.

Moderator Campbell: Has Mr. Wrist any comment about measuring suction at the high speeds?

Wrist: There are two remarks I would like to make in connection with the theory.

One really arises out of Mr. Whitney's paper this morning, in which they report a discrepancy of a factor of 4 between the two equations of drainage. This arises because they made the assumption that the pressure was constant over the nip. As an actual fact, the theory and the experimental results do show that the pressure builds up from zero to a maximum. Therefore, the average pressure over the nip is half the maximum pressure. Since the pressure term comes into the equation of drainage as the second power this gives a factor of four.

And the other fact which I'd like to comment on is the dependence of drainage on speed. If you look at the equation the first impression is that the drainage should go up as the cube of the speed, and no papermaker believes that. The reason for this is that in the denominator is the resistance. We have seen that due to the compressibility of the pulp as you raise the speed and thereby increase the pressure, you increase the resistance.

Both introduction of experimental determinations of pulp compressibility into the equation and the actual machine determinations of the dependence of water drainage on speed show that the equation reduces to approximately a half power law. This, I think, does fit in fairly closely with practical observation.

Moderator Campbell: Are there any other comments on Mr. Bennett's paper?

Steenberg: My first question is, what will happen to the wire—the suction off the table roll will in all probability deflect the wire?

Could you follow what I meant by that? May I use this (indicating blackboard)? Now this is the (using blackboard and drawing) table roll, and the wire moving in this direction. Now, if you have a suction area after the roll of the order of 20 in. of water, that is a very heavy load on the wire. The wire must deflect. How does it deflect? And what will come out?

The high pressure is in the very first area after the roll apex, and there is a fairly long distance between the table rolls, so there is quite a possibility for the wire to sag. I would believe that if I put a suction of this order to the wire, the

wire would rest on the table roll for a considerable distance. So, I believe that the wire will look like this (drawing). With this heavy pressure it must definitely be pressed down in some way.

Now, there are some important things to remember here. All that power to draw in water must be supplied by the couch motor, because you don't put any energy into your machine in any other place and that work has to travel along the wire. If this high suction exists, it would be quite interesting to have a value of the actual tension in the wire while it is running, which, of course, is entirely different from the tension in the wire when it is still, or the tension on the slack part of it.

Maybe the work which you have to apply to take out the water will stress the wire and tighten it so much that it does not deflect proportional to the increased suction with speed, and then these two effects cancel out in some way. At any rate, I think the deflection of the wire is something you have to take into consideration.

May I use two more seconds on this, because we have worked on it a little, using an optical method to determine the surface of the running wire with stock on it. If you have a line and take the mirrored image of that in the wire, you will get a distorted line—from this you can recalculate the profile of the surface. Then we had to know the form of the wire. We started to assume that the wire was flat. With the accuracy of optical approach, we found that was a very poor approximation.

The next approximation of the form of the wire was to treat it as a stretched beam under point supports. That theory was not of any value because, (1) you do not have point contact and (2) you have inertia effect. The catenary, the chain line, will not have its apex in the center between rolls.

Furthermore, I am asking the author, now, if you measured on the top of the water-film a suction of the order of 20 in. of water, what is the suction under the wire? The suction there must be a much higher figure, because you have a lot of pressure lost, passing in the wire and passing through the layer of fiber which rests on it, so the actual suction down here is probably many times.

Did you measure this with just water on the wire?

Bennett: Yes we did.

Steenberg: If you measure it with just water on the wire, you have entirely different conditions because you have a transparency of the wire which has nothing to do with the transparency of the wire when you have stock on it.

I think the calculation of the form of the wire when it is running is of tremendous importance, to be able to understand sprays and similar things.

I am now coming over to my second question. Here, with our optical method, we can determine the surface of the moving wire, the surface of wire (water) on the moving wire, with an accuracy which is definitely better than 0.001 in. when the speed is up to say 500 or 600 ft.

We find that the hump is not over the apex of the table roll. It comes off that. At higher speed, that hump travels up, and the horizontal distance from the top of the hump and top of the table roll is dependent on the square of the speed. At some speed, eventually the top of that hump will be thrown off in the form of a drop. And then, of course, you have the secondary form of substances that come up roughly at this distance (indicating).

Now you exactly measured pressure, and you said the pressure was zero above the roll. Now you see this area is certainly of some definite interest, where you pass through the plumb line, because I would believe you had zero pressure on this side (indicating negative) and not exactly at the apex of the roll. But of course you have to make very delicate measurements, and it is very difficult. The optical method is even too sensitive for this thing.

I would like to hear comments on the inference of the form of the wire which is the most important thing, I think.

Bennett: If I might deal with the last point first, as you say, we had a very small amount of space to work with in the measurements over the top of the roll, and while I did, in fact in my diagram say top dead head center, we were not sure. We suspect it was a little bit over.

But in these other experiments, which I just mentioned here, where we take the measurements underneath, we can see much more clearly now that the point of zero in pressure is, as you suggest, over on that side, and that is a consequence, I think, of the thing which Mr. Underhay was mentioning—the wedging of the water—some water being carried under, some being carried on the roll and being wedged up there. And so the suspected top dead center is misplaced to a certain extent.

In connection with this profile of the wire, and to what extent that is going to be useful, I feel I should move over to the board for that.

I am not at all convinced that the profile, the top profile of the stock, would necessarily follow the profile of the wire.

Steenberg: May I interrupt—no—the profile of the wire was determined with just a film of water on it.

Bennett: Yes, but even then I think with water on the wire, you might expect something rather like this (drawing on blackboard). I will exaggerate very much the thickness of the water film, to come up here somewhere, and then as it moves over top dead center, and over the area of the nip it comes like that (drawing), and would achieve this new level here, and the nip of water is in there.

The profile of the wire itself will follow that of the stock surface to some extent. I think that it will come down like that (indicating). However, it will not necessarily be the same.

On this question of power consumption, it is quite obvious that we cannot get something from nothing and power must be transmitted along the wire. It would be a most interesting and informative thing to measure the natural tension of the wire at these speeds.

As I say, the machine that we use or did use had many advantages for us. However, when you are doing mill experiments you find that you can never get everything as you want it and, after all, the machine was tied up with belts and pulleys and so on and therefore we could not get any sensible information on our power consumption rates. I think that this is something that would lead to a lot of useful information.

Does that answer the question?

Steenberg: I think that you have answered the question. We seem to agree that if a suction of 20 in. exists, the wire must be pretty well deflected in that area and it may make a considerable area of contact with the roll. You will agree that as long as you have that contact area you cannot get anything out.

Bennett: That is true and that is something that is hard to explain.

Of course, this question of the wrapping of the wire on the roll, which we have known for a long time, people have tended to attribute it to the surface tension forces, but it seems to me a question of fluid friction going through the wire.

Steenberg: Yes.

Moderator Campbell: Are there any further questions or discussions?

Mardon: With regard to the wrap of the wire on the roll, there are some good photographs of it at about one five thousandths of a second* which show this wrap very well and some of the photographs show the various degrees of the wrap of the wire on the roll at different parts of the wire.

I have a definite question for Mr. Bennett in regard to his paper, where he discusses the increased drainage that he finds at his table roll no. 2.

* Made by F. W. Perry (now of Peter Dixon) who worked with Mr. Mardon and by Bernard Browning of Bowaters.

In fact, might it not be possible that the increased speed caused a further deflection of the jet down the wire and so greatly reduced the drainage at the breast roll and consequently caused an enlarged drainage at the first tube roll and at the second one?

BENNETT: Well, I am trying to remember exactly what the machine did at the time. There was a good deal of kick-up from the roll but I did not think that it would be directly effective at roll no. 2 by the profile of the jet.

MARDON. I am sorry, Mr. Chairman and gentlemen, but it seems that Mr. Bennett did not understand my question.

The jet from the slice is actually a free jet of some distance, and the important thing in operating any medium and high-speed machine is the actual position of the impingement of the jet on the wire relative to the breast roll suction area. If there is a large breast roll discharge, even when one is running a machine at the medium speed of 1500 ft., an alteration of 50 or 60 ft. is sufficient to deflect the jet a little further down the wire and thus much less water is taken out by the breast roll, and, of course, it goes on a little further. Therefore, when one increases machine speed, one normally adjusts the position of the breast roll to catch up with the jet if water is being deflected down the breast roll and if it is desired to maintain the same proportion of total drainage at the breast roll.

BENNETT. Well, first of all, during this series of experiments we didn't alter the position of the jet, the slice, or anything. We left that quite rigid and constant.

Secondly, the first roll and the breast roll—we could not distinguish between them. We could not collect these flows separately and that got rid of a lot of problems. It was a convenient rag bag for all of these awkward effects which might have happened. They are all lost in the first trough, which drains the breast roll plus the first roll together.

WRIST. Possibly I can answer part of Mr. Mardon's question by saying that this particular machine was going about 700 f.p.m. and, as I remember, the jet impinged on top dead center of the breast roll or a little bit before, so that there was no alteration of breast roll discharge.

Does that answer you question?

MARDON. Thank you.

LEE: Here is a comment from Eli Cowan which first indicates that this is a splendid paper. "The inadequacy of the gravity theory was most forcibly brought to our attention by a power distribution analysis on a high-speed kraft machine where required water drainage is enormous. The power required to drive the table rolls is most startling. Power measurements could be correlated to suction. We have always been troubled by the necessity of treating the velocity factor as a constant in the gravity equation. Work done by the British research group is already a significant contribution for assessing the various physical factors in the design of the coordinator."

There are some other questions here.

"It was stated that efforts have been made 'to get the water further down the wire' and that the water removal 'may be too fierce.' Why should not the water be taken out early and rapidly if the means to do so are at hand?"

BENNETT: Well, in connection with Mr. Cowan's comments, I have had no practical experience myself of just what power is required to take out the water by the table rolls and if he has been able to estimate the power required to turn the table rolls over, then I am sure that it would be most interesting to know.

In connection with the other point, I am sure that a lot of other people here are more competent to answer that one than I am. Why, if we can get it in the early stages, then don't we? I think that is about all of the comments that I have there and maybe somebody in the audience would care to comment further.

I might mention another point which occurred to me fairly late in this analysis.

We are, of course, familiar with the idea of the forming board and other devices for moderating this flow and the question of shaped scrapers seems to be rather interesting. The idea of the scraper underneath the wire was originally to scrape the water off from underneath the wire but some of these scrapers now seem to have a convex back surface and there, again, I think that you probably can get more drainage.

As I said this morning, the stopped table roll is sucking apparently at half the suction when it is going and so while you have the front edge of the scraper board actually scraping, the trailing edge is doing a little sucking.

LEE: I have another question here.

"The no. 16 table roll apparently removes more water than the no. 15 on that particular machine. Moreover, this result has been repeated. Is this not significant and is it possible to find why one roll will remove more than expected?"

BENNETT: Now, I think I mentioned that this morning, and I am still quite mystified as to how it happened. I am quite convinced that it is not a question of the surface of the roll or how true the roll was or anything like that. It is a question of the position on this machine.

LEE: It poses a question. Is it not possible that the water in the fibers could redistribute at some place down the wire to effect the more efficient removal at the common point in the wire?

BENNETT: Yes.

LEE: I have one last question and I think that this has been covered in the data or discussion.

"An extrapolation of your data indicates that 30 in. of mercury would be reached at a speed of 2500 f.p.m."

I think that we have dealt with that already.

MODERATOR CAMPBELL: That concludes the discussion of Mr. Bennett's paper and so we will pass on and ask Mr. Sankey to make his comments upon the paper of Mr. Andersson.

C. A. SANKEY: Mr. Chairman, Mr. Andersson's paper is concerned with the stage of papermaking on the paper machine prior to that of the previous speakers.

I cannot help commenting, as a Canadian and in view of many remarks to the effect that, in general, Europeans tend to be more theoretical than our friends on this side of the border, who tend to be more practical, that in the present circumstances I notice a distinct reversal of this approach.

Now, in commenting on Dr. Andersson's paper, as he knows the regular commercial practice on all machines has been to operate under such conditions that the rate of flow from the size of the jet is from 80% to 95% of wire speed. That has been done for years and, as a papermaker will tell you, it is the only way to make paper. If he happens to be a little bit more specific, he will say that if the speed of the slice discharge gets too fast it will make a heck of a mess on the wire and he will not say "heck" either.

Still a third explanation which I have heard is that you have to comb out the fibers a bit in order to make a good sheet of paper, which of course raises the question of the explanations offered by Mr. Andersson for his results and for which he was going to get into an argument with Mr. Van den Akker and Mr. Mason.

A most interesting point in the paper to me was the explanation offered by Mr. Andersson for his results because you will recall that in terms of his experiments he arrived at exactly the same conclusions that the papermakers have arrived at long ago, that the ideal condition was to operate at about a 10% differential between the start speed from the slice and wire speed. Now, Mr. Andersson's explanation was, if I understand his paper correctly, that it was largely a matter of difference in the velocity going through from the top of the surface on the wire through to the wire itself because the bottom is slowed down by frictional contacts.

I think that perhaps Mr. Andersson might like to comment on the relative validity of the older explanation and on his

own and I would also like to give him a chance to pick a fight with the two gentlemen that I previously mentioned.

ANDERSSON: Thank you very much.

This thing about 80 to 90% is fairly well known since the time of Bryan and Donkin. That is very recent and people sort of expect me to stick to it.

I am slightly . . . I am sorry to hear that my paper was misinterpreted because with regard to the unit period, it was my intention to try to kill that.

It was mentioned that the optimum speed of the stock could be expected to increase with the speed of water, but I think that my results still cannot prove that the optimum conditions occur at a specific percentage.

As I interpreted the paper, I got the impression that it rather disproved than proved its point.

I think you are all justified in believing that these optimum conditions occurred at different percentages. There is probably much more involved in relationship all through the measurements which we have been able to do and as a result they are more practical to make the distinction.

As far as Mr. Van den Akker is concerned, I would like to hear from him for a couple of minutes and I would be happy to answer any of his questions.

VAN DEN AKKER: My remarks on fiber orientation—or absence of orientation—were appropriate to free flow of a slurry, not to what happens on the wire of a paper machine.

SANKEY. I think that perhaps the common ground between Mr. Andersson's and my own comments are that for each particular paper machine and for each particular set of conditions, there is one ideal condition which is found in practice by the papermakers and in the terms of their own production.

Mr. Andersson is interested in trying to find a more valid and independent basis and I think that we are on common ground.

Do you agree with that?

ANDERSSON: Yes.

UNDERHAY: I would suggest that this term "optimum" is a little confusing. My question would be—optimum for what? I think it is important to know whether it is optimum to make a square sheet, which you are talking about, or whether it is optimum to make a grainy sheet. I think it is rather confusing to be using the word optimum when you don't know which one.

ANDERSSON: I have found only one optimum; the square sheet that creates optimum in the sheet formation. I did not find an optimum in any other.

SANKEY: The real optimum is optimum production.

MODERATOR CAMPBELL: Are there any more thoughts and arguments on this point? Apparently silence prevails and so I will ask Mr. Foote to make his comments on the paper by Mr. Underhay.

FOOTE: Mr. Underhay puts me in the unhappy position for discussion here of nothing but complimentary things.

He has presented factual data which seemingly cannot be contradicted.

He has devised a laboratory technique which covered fully the problems which he encountered.

He has translated the results therefrom to practical limitations in a paper mill.

Now, I am forced to say that I can only agree with him. I think that the main question that we can go to from here is—where do we go from here?

Now, before I introduce some of the questions which came from the audience, I would like to make a few of my own.

All of your two-sided necessary determinations on handsheets were visual and I wondered whether you used your stripping method for determining the ratio on both sides?

UNDERHAY: No, they were all visual determinations. However, I can say that they did give the ratio of 2 to 1 and I apologize for not actually including them.

FOOTE: Your paper has me almost convinced that two-sidedness is developed in the table rolls; I would like to have you comment on Hanson's remarks in *Tappi* in April of 1951 where he stopped the paper machine with the stock on the wire, let it dry there several days, and then cut strips off the wire in various positions. A particular sample taken 3-ft from the slice showed the same distribution curves that you have. There was a higher concentration on the felt side of the sheet than on the wire side.

I wonder if you would comment on that?

UNDERHAY: Frankly, I find it a little hard to understand that. As I see it, if you slow a machine down from a thousand feet a minute or whatever it is, it has to pass through that 80 f.p.m. range which I showed you, and I am sure that at 80 ft. you can make a completely non-two-sided sheet and just how you can slow it down to zero and find that it is not two-sided, I don't know. That does not tie up at all.

FOOTE: I have but one question here. "If there is but little difference in printing characteristics between the felt and wire sides of your loaded sheet, why is the top side preferred for the top cover of your magazine?"

UNDERHAY: That is a very sound question. I think that I have the answer to it.

I would like to define "printability" and that is something that is very difficult. I tried to narrow it down to the faithfulness with which the surface reproduces the typing faces irrespective of any color differences. You can only be irrespective of the wire mark if you get a sheet which happens to be singly free from wire marks but the color difference is still there and I think that the difference is sufficient to choose the top side because although the faithfulness of reproduction may be the same on both sides, you will, in fact, get a better impression of printing because of a brighter shade showing up there.

SANKEY: With all due respect to you today I have to add that I have never met a printer who refused to see the wire side.

MODERATOR CAMPBELL: We will proceed to the next paper. Mr. Blickensderfer will comment on the paper by Mr. Nordman.

P. S. BLICKENSDERFER (Champion Paper & Fibre Co.): The paper which Mr. Nordman presented was most interesting. All of us who work in the paper industry are interested in methods that more closely simulate paper machine conditions in the laboratory. It is usually cheaper to work in a laboratory than on an expensive production machine. Also the laboratory presents the additional advantage of better experimental control. So far in this symposium, several very interesting pieces of equipment simulating machine conditions have been described; in particular the one by Mr. Steenberg, and now I have the pleasure of commenting on one by Mr. Nordman.

I believe you will agree with me that the design of Mr. Nordman's experiment was novel, and that his equipment was most ingenious. It is gratifying to know that it is possible to express in simple terms, suction conditions on the paper machine, and therefore be able to build a rather simple piece of apparatus to reproduce these suction conditions in the laboratory.

Mr. Nordman has, indeed, done a good job of simulating some of the paper machine suction conditions, particularly in connection with the suction boxes and couch roll. But no doubt he, and all of us, will agree that the simulation is by no means complete. This situation is no criticism in the adverse sense, but should be mentioned.

I have been thinking of Mr. Underhay's paper, where he showed that machine-made papers, at least under the conditions that he used, were two-sided, and that the sheets produced by straight suction conditions in the laboratory were not two-sided according to his test. In Mr. Underhay's case the criterion of two-sidedness was ash content gradient.

It might not be unreasonable to assume that a steep cellulose "fines" gradient would exist in machine-made paper but does not exist in paper made under suction conditions in the laboratory. This difference between machine-made and laboratory-made may influence dryness results.

There are many men in the audience who know much more about this phase of the work than I do; I would appreciate hearing from some of these people, particularly Mr. Brecht and Mr. Gallay, as to what possible influence these differences might have.

Then, going to Mr. Nordman's results, I had written down here a comment on freeness, but I think you all will agree with me that has already been adequately covered.

I feel that this is perhaps an obvious point, but perhaps should be brought out, namely, that Mr. Nordman referred to the influence of fines on dryness, which, incidentally, is one of the more important influences on dryness. His results involved one set of papers containing fines solely from groundwood, and another set containing groundwood fines and hydrated fines from chemical pulp.

To classify fines merely by the word "fines" does not, perhaps, characterize them adequately. Perhaps some of the people who are more versed than I am in the theory and practice of filtration, might comment on any possible influence the different types of fines might have on Mr. Nordman's results.

I feel that Mr. Nordman has done us a great service to point out the possibilities of a new technique, and would like to hear what you men think about it.

I might say, in conclusion, that Mr. Nordman was, as you know, the last man on the program before the panel discussion, consequently I have the misfortune of announcing that I have no written questions to present to him. This is all the more reason why you men who do have ideas, or have had experience along these lines should speak up and not in any way be hesitant.

Thank you very much, Mr. Chairman.

Brecht: I don't know whether I am able to make any comments which are of any value. As a matter of fact, years ago we did a little work in about the same field as Mr. Nordman did. We always were interested in determining the dry content of the sheet at the couch roll in the laboratory because it is of the greatest importance for the wet web strength. I am looking forward to the paper tomorrow by Mr. Gallay on wet web strength.

What we did in finding out the dry content of the wet sheet at the couch roll was the use of a sheet forming device in which the wet sheets were made for strength testing. Drainage was divided in two parts, the first, the free drainage of water, the second drainage under vacuum. We thought it advisable to use two figures for characterizing the drainage properties of the sheet. The first period of drainage gives a number which refers to the free dewatering as it occurs on the table roll. The second number characterized the dewatering property of the stock as it is, well, as it occurs in the suction part of the paper machine. We obtained interesting values, which could be used for an equation. This equation gave in an empirical way about the same values as were measured at the suction couch of a certain paper machine.

I am convinced that the method he described this morning is much better than the method we used. Nevertheless, we could find that for machines, running with a speed of 1200 f.p.m. producing paper with a substance weight of about 50 to 60 grams per sq. m. The results checked quite all right indeed with the dry content we figured out by means of the two dewatering values developed in the laboratory.

We didn't use a dynamic method. We used a primitive static method, and I do not think it necessary to describe it here. I certainly liked very much to hear that Mr. Nordman has developed such a fine apparatus, because we all know what the dry content of the wet web sheet means, and how useful it will be to get a laboratory method which is able to give us values which are, especially in the case of fast running machines, very difficult to obtain.

Another question, perhaps I could refer to, is the term "the fine particles," because we must distinguish between what we call the mucilage and the floury parts of the fines. These two sorts of particles, have a very different influence, in every regard as to the properties of the sheet, whether it is wet, or whether it is dry.

What I would like to hear, or what Mr. Nordman would be so kind, perhaps, to explain a little better, is the kind of fines to which he referred. As far as I could understand there was no difference made between these two kinds of fine particles. Is that right?

Nordman: The fines I was referring to in my graph were the fines which passed the wire which we used in our test. It was not meant as an experiment to discover the different behavior of the different kinds of fines. It only illustrated that the fine fibers passing through the wire will influence the dryness of the sheet, and I am quite convinced that if we have different types of groundwood pulp we will get different slopes on this curve.

Gallay: I wonder whether I might emphasize something which probably doesn't need repetition; that is, that the web strength depends on the quality of the pulp in the wet web, and it depends on the moisture content of the web.

Now, if you use a constant vacuum for your water removal, then you arrive at a certain wet web strength. But it is a mixture of the quality and quantity factors, because in some cases you will have the type of pulps in the web which will give you a higher moisture content or a lower moisture content at a certain vacuum, depending on the system you have available.

From the strictly practical point of view, if you are interested in a certain mixture of pulps, then it is probably sufficient, simply to use a constant vacuum and arrive at a definite wet web strength.

But from the more academic point of view, the more abstruse point of view, it is strictly necessary to separate the quality factor from the moisture content factor.

I am quite sure that both Mr. Nordman and Mr. Brecht are quite well aware of that, but I wanted to emphasize that as a very important phase of this whole matter.

Blickensderfer: I believe that Mr. Brecht and Mr. Gallay's remarks, to a large extent, answer some of the questions I raised.

I think in fairness to Mr. Nordman that we should consider the fact that he is introducing a new method, and as he has just very ably pointed out, his results are of secondary importance.

What advantages are there in this new method, aside from the close duplication of machine suction conditions?

Moderator Campbell: I see Otto Brauns put up his hand for a question.

Otto Brauns (Swedish Wood Research Institute): In taking Fig. 5, there is one thing that I would have liked the author to have elaborated upon since it is of practical importance. You are increasing the dryness, as you go along with time. Now, what would have happened if you had increased the vacuum in steps and still maintained small time for each step? Would you have reached any given dryness sooner? It seems to me that you are withholding something from us. You must have made that experiment

I mean to say that as the sheet travels over a vacuum box at constant vacuum, capillaries up to a certain size will drain; and if you want to drain more water the capillaries will be of a smaller size, and you would have to apply a higher vacuum. The figure might convey wrong ideas to the papermaker.

It does not matter however long you make your box. You see, you would never drain more than a certain size of capillaries for any given vacuum, and your experiments

could have given us the time factor involved. Isn't that right?

So, we shouldn't believe that this curve is going up all the time, so that by increasing the length of a suction box, we would get more and more water out. Mr. Nordman is certainly aware of this. That is why I should like his further comments on the diagram.

NORDMAN: Mr. Brauns is quite right when he states that the curve should level out, but we haven't been able to do these experiments with this rapid machine because the suction time was limited by the speeds which we could produce.

But if we are using another type of drainage tester and applying suction for longer times, we will find that the curve will eventually level out, perhaps after a second or two.

Also, if we increase the vacuum we reach a higher dryness of the sheet than we have shown in this investigation. We have made investigations on these lines, also.

SHOUMATOFF: I would like to suggest a possible answer to Mr. Blickensderfer's question, and that is the possibility of using the laboratory suction box to correlate it with the result obtained by Mr. Whitney in the drainage. I think that basically they are the same phenomena.

Of course you have the mixture of air and water; and Mr. Nordman said that the mechanism was that air entrains and carries the particles of water. Actually I believe it is more useful to visualize a two-phase fluid flowing with the pressure gradient. There was some work done by Brownell and Katz (*Chem. Eng. Progress* 43: 537, 601, 703 (1947)) on rotary vacuum filters, where they studied rather fundamentally the flow of mixtures of air and water through pulp mats. I suggest that a similar approach could be of interest for quantitative correlation of the suction box data.

NORDMAN: I think that the suction box is not so clean an instrument as the other instruments we have heard about today.

I think that the application of hydrodynamics to this problem will give rise to widespread difficulties, just because we have two different phases. We have the phase over the same sheet where water passes through the machine; and the second one where air also is going through. I think that the relativity between the two areas will make a mathematical treatment difficult. It will be very difficult to calculate how large is one part and how large is the other.

Certainly it will be very interesting to see the correlation between the results obtained with this instrument and the actual dryness we can obtain on the paper machine. So far we have not done anything along these lines.

SHOUMATOFF: Mr. Nordman, some of the data which you presented this morning show that the temperature plays a very important part, which is similar to what Mr. Bennett says happens on the second half of the table roll, which would indicate that it is the Kozeny type of flow which is governing; also, that the beaten pulp was harder to dry than the unbeaten pulp, which would bring in the specific surface concept.

NORDMAN: Yes, that's quite true, the same principles are involved, but I think that it is a very difficult task to calculate surface area from data obtained with this design.

NISSAN: I would like to draw your attention to one phenomenon which complicates the problems touched on by everybody up to this time.

One thing that strikes everybody coming into the machine room of a paper mill for the first time is the fact that paper appears to be made out of rain; the rain to which I refer is at the slice. I have never seen a machine where the flow from the slice onto the beginning of the wire at the press roll was smooth.

What I have observed and what everybody else has observed is a mass of drops, a large number of them, probably by the thousands, which we can see with the eye, going up along a parabolic trajectory and then falling on the water. Studies of drops falling on water by high-speed photography give some very beautiful pictures of craters, each with a little coronet, with knobs on each of the points. These knobs themselves break and fall over, creating some more disturbance.

What I am referring to particularly is that practically each one of these has a little air bubble attached to it when it settles down.

Furthermore, in the stock that we have there are fibers. It is amazing how difficult it is to deaerate those fibers. If, for instance, you want to measure the density of a single fiber, you will find that you will have to boil it for quite a long time under a vacuum to deaerate it and get the density of that fiber properly.

Now, what do we then have? There is a stream, not of water and fiber, but of water, fiber, and air. That will interfere with every phenomenon here.

I want to draw particular attention to one item which was mentioned and that is at high speeds you can calculate the suction by Mr. Wrist's theory and you will find that you approach the barometric pressure at fairly attainable speed. I want to emphasize that if we should ever measure it and find that suction is not reached it does not disprove Mr. Wrist's theory, because if you take an aerated liquid in a pump and start the pump, you will find that you approach a certain vacuum and that you stop at it because the air comes out. Therefore, if we should ever measure this and find that the pressure is not the value that Mr. Wrist has given, it does not disprove his theory. His theory is proved if we measure it with water. When we do that we find that it is approximated and that it is sufficient to prove that.

Now, the second point is that we have all attempted to duplicate things on the machine from a drainage point of view but in our apparatus we do not have the aereation property. We have a two-phase flow in our operation and a three-phase flow upon a paper machine. In our test apparatus we even try to produce a one-phase flow.

Now, anyone that has done some work on permeability appreciates that a two-phase flow is different in characteristics from the single-phase flow and therefore again the catch will be that it will be a devil of a test to try and duplicate machine conditions in a laboratory test. I wonder why we want to duplicate it but then that is your problem and not mine.

A third point that I would like to mention is in connection with the other paper. Mr. Steenberg has mentioned it and Mr. Mardon has pointed out that when photographs were taken of the wire the dip is quite observable. You can see it but it doesn't wrap itself around the wire.

The wire is stiff, it is rigid, and it is moving forward with some speed but still it does dip.

Now, what this means then is that it does form a bend as it goes from one roll to the other and therefore there is a further complication in Mr. Underhay's theory, in that you will have a shock wave at the tip, at the apex of the roll, even if you wipe that roll clean of water and therefore, once again, we have a little bit of complication in the detail of hydrodynamics which has to be taken into account.

However, there is also a little pumping, not only of water, but of air also into the fiber and that fiber is again being churned by this boundary layer of air which is going in.

Therefore, the point that I am trying to make is that when we talk of water going on as a stream, then all these considerations make a system which is not a single-phase system but a three-phase system of water, fiber, and air,

Now, if you really want to duplicate results with laboratory equipment, I think that you want to aereate your liquid and to really mess it up before you do something with it.

MODERATOR CAMPBELL: Thank you, Mr. Nissan. Now, it is just past 5:15. I want to thank all of the people who have taken part in this discussion and I want to say that it has been one of the best discussions that I have ever encountered. Everything has been to the point.

ASSOCIATION NEWS AND EVENTS

Local Section Meetings

Pacific: Jan. 11, 1955, Longview, Wash. Pulping Session; March 4, 1955. Everett, Wash., Shibley Award Program.

Kalamazoo Valley: Dec. 2, 1954, Hotel Harris, Kalamazoo, Mich., "New Testing Methods"; discussion led by Paul D. Applegate, Hercules Powder Co., Kalamazoo, Mich; Jan. 13, 1955, joint meeting with the Michigan Div., APPM Superintendents Association.

Southeastern: Jan. 14–15, 1955, Francis Marion Hotel, Charleston, S. C.

Lake States: Jan. 11, 1955, Conway Hotel, Appleton, Wis., "Chromatography for Control and Research in the Pulp and Paper Industry," by Edgar Dickey, The Institute of Paper Chemistry, Appleton, Wis.

New England: Dec. 10, 1954, Roger Smith Hotel, Holyoke, Mass.

Ohio: Dec. 9, 1954, American Legion Hall, Middletown, Ohio, George H. Pringle, Mead Corp., Chillicothe, Ohio, and President of TAPPI, speaker; Jan. 11, 1955, Manchester Hotel, Middletown, Ohio, "Some Aspects of Stock Preparation," by Alfred H. Nadelman, Western Michigan College, Kalamazoo, Mich.

Lake Erie: Dec. 11, 1954, Hotel Carter, Cleveland, Ohio, Christmas Party; Jan. 14, 1955, Hotel Carter, "Materials Handling."

Delaware Valley: Dec. 10, 1954, Engineers Club, Philadelphia, panel discussion "Latest Developments in Beater Additives."

Empire State (Metropolitan District): Dec. 14, 1954, Fraunces Tavern, New York, N. Y., panel discussion "Customer Demands and Sales and Manufacturing Problems Arising Therefrom": Jan. 11, 1955, Fraunces Tavern, "Comparison of Various Pulps from a Use Aspect," by Gerald Haywood, West Virginia Pulp & Paper Co., Luke, Md.

Empire State (Eastern District): Nov. 18, 1954; Dec. 16, 1954; Jan. 20, 1955; Feb. 17, 1955; March 17, 1955; April 21, 1955; and May 21, 1955. Glens Falls, N. Y.

Empire State (Northern District): Dec. 9, 1954; Jan. 13, 1955; Feb. 10, 1955; March 10, 1955; April 14, 1955; May 12, 1955. Woodruff Hotel, Watertown, N. Y.

Empire State (Western District): Dec. 1, 1954, Prospect Hotel, Niagara Falls, N. Y., "TAPPI, the Right Arm of Pulp and Paper Management," by R. G. Macdonald, Secretary, TAPPI, New York, speaker.

Empire State (Central District): No meeting schedule received.

Foreign Pulp and Paper Technical Association

Following are the names of the presiding officers of organizations throughout Europe that have approximately the same type of objectives as TAPPI:

R. B. Jeffries, President, Australian Pulp and Paper Industry Technical Association

Jean Vilars, President, Technical Association of the Paper Industry (France)

H. Muller-Clemm, Chairman, Association of Pulp and Paper Chemists and Engineers (Germany)

Otto Wurz, Vice-Chairman, Austrian Association of Pulp and Paper Chemists and Engineers

Oswaldo Emery, Chairman, Italian Association of Paper Technologists

L. C. Carlsen, Chairman, Danish Association of Paper Technologists

Henning Wadell, Chairman, Swedish Association of Paper and Pulp Technologists

Heikki Sihtola, Chairman, Finnish Association of Paper Technologists

C. A. Knudtzon, Chairman, Technical Association of the Paper Industry (Norway)

G. F. Underhay, Chairman, Technical Section, British Paper & Board Association

The TAPPI Fibrary

Five years ago the members of TAPPI were contacted as to authentic specimen fibers they would be able to supply the Association for the purpose of organizing a fiber library or "Fibrary." The response of the membership was gratifying to those members who promoted the project.

The Institute of Paper Chemistry, which had agreed to act as custodian of the samples, carefully sorted the offers received to eliminate duplication. Considerable effort on the part of the many donors as well as the custodian during the ensuing year resulted in the publication of the first catalog in the February, 1951, issue of *Tappi* (*Tappi* 34, No. 2: 26A). This initial catalog listed 194 fiber samples ranging from ambari hemp to yawa fiber. The first addendum to the catalog was published in the September, 1952, issue of *Tappi* (*Tappi* 35, No. 9: 178A) and brought the total number of samples listed to 359. A second addendum of approximately 30 fibers is being prepared and will be published in an early issue of *Tappi.*

Those in charge of the Fibrary have attempted to obtain authentic samples (covering a wide range of pulping processes, degree of cooking and bleaching, etc.) of both commercial and noncommercial species. Anyone having samples not previously listed is earnestly requested to contact the fibrarian.

Since its inception there has been a steady, albeit relatively small, demand for samples from the Fibrary. Orders have run the gamut from one sample to the entire listings. Generally, one must conclude that TAPPI members and others in the industry have found this to be a useful service.

In conclusion, it may be well to emphasize that a representative specimen of each fiber may be obtained from the TAPPI Fibrary, The Institute of Paper Chemistry, Appleton, Wis. Each sample has a number which may be used in ordering. (Reprints of the catalog will be sent on request.) A service charge of 25 cents ($0.25) per sample has been established to help defray the cost of handling, packing, and postage. Remittance of the necessary fee at the time of ordering will help to keep these costs as low as possible.

Inquiries about the TAPPI Fibrary should be addressed to Irving H. Isenberg, The Institute of Paper Chemistry, Appleton, Wis.

Fundamental Research Conference

"Fundamentals of the Paper Machine" was the theme of the Fundamental Research Conference held at The Institute of Paper Chemistry, Appleton, Wis., on Sept. 21–24, 1954.

A part of the group at the Fundamental Research Conference

Harry F. Lewis of the Institute was the general chairman of the conference which was attended by 283 individuals.

Since the papers presented, together with the discussions, will appear complete in the November and December issues of *Tappi*, no general story of the conference was published. The names of the individuals who attended this international meeting jointly sponsored by the Fundamental Research Committees of TAPPI and the Technical Section, Canadian Pulp and Paper Association, follow:

Speakers, Discussion Leaders, and Chairmen

Andersson,* O., Pulp and Paper Research Inst. of Canada; Physical Chemistry Div., 3420 University St., Montreal, Que., Bennett, H. W., Kimberly-Clark Corp., Neenah, Wis.; Bennett, W. E., The British Paper and Board Industry Research Assn., St. Winifred's Laboratories, Welcomes Rd., Kenley, Surrey, England; Bennett, W. T., Chief Engineer, Canadian International Paper Co., Sun Life Bldg., Dominion Sq., Montreal, Que.; Blickensderfer, P. S., Asst. to the Director of General Research, The Champion Paper & Fibre Co., Hamilton, Ohio; Brauns, Otto, Director, Central Laboratory of the Swedish Paper Mills, Kristinas väg 61, Stockholm Ö, Sweden; Brecht, W., Institut fur Papierfabrikation, Technische Hochschule Darmstadt, Darmstadt, Germany; Burkhard, George, Mill Research Director, Quebec North Shore Paper Co., Baie Comeau, Que.; Calkins, C. Richard, Riegel Paper Corp., Milford, N. J.; Campbell, W. B., Pulp and Paper Research Inst. of Canada, 3420 University St., Montreal, Que.; Chapman, Joe, Albert E. Reed & Co., Ltd., Aylesford Paper Mills, Larkfield, NR, Maidstone, Kent, England; Clark, James d'A., Longview, Wash.; Davis, M. N., Kimberly-Clark Corp., Neenah, Wis.; Foote, W. J., Consolidated Water Power & Paper Co., P.O. Box 315, Stevens Point, Wis.; Gallay, Wilfred, Director of Research, The E. B. Eddy Co., Hull, Que.; Griesheimer,† R. N., The Mead Corp., Chillicothe, Ohio; Ingmanson, William L., The Institute of Paper Chemistry, Appleton, Wis.; Ivarsson,* Bertil, The Beveridge Paper Co., Indianapolis, Ind.; Lee, C. A., Kimberly-Clark Corp., Neenah, Wis.; Logan,† K. C., Northeastern Paper Products Ltd., P.O. Box 1456, Quebec, Que.; Lyne, L. Murray, The E. B. Eddy Co., Hull, Que.; MacLaurin, D. J., The Institute of Paper Chemistry, Appleton, Wis.; Malmstrom, Homer E., Basic Research Laboratory, Kimberly-Clark Corp., Neenah, Wis.; Mardon, J., Research Engineer, Northeastern Paper Products Ltd., P.O. Box 1456, Quebec, Que.; Mason,† S. G., Head, Physical Chemistry Div., Pulp and Paper Research Inst. of Canada, 3420 University St., Montreal, Que.; Nissan, Alfred H., Dept. of Textile Industries, The University, Leeds 2, England; Nordman, Lara, Oy Keskuslaboratorio-Centrallaboratorium Ab, Hesperiank 4, Helsinki, Finland; Porter, Cover C., Southland Paper Mills, Inc., Lufkin, Tex.; Rance, H. F., The Wiggins Teape Group Research Organization, Glory Mill, Wooburn Green, High Wycombe, Bucks, England; Sankey, C. A., Research Director, The Ontario Paper Co., Ltd., Thorold, Ont.; Schelhorn, Fred B., National Container Corp., P.O. Box 1620, Jacksonville, Fla.; Shinn, Dalton L., Crown Zellerbach Corp., Experimental Papermaking Section, Central Research Dept., Camas, Wash.; Stamm, Alfred J., Subject Matter Specialist, Forest Products Laboratory, Madison, Wis.; Steenberg, Börje, Swedish Forest Products Research Laboratory, Paper Technology Dept., Kristinas väg 61, Stockholm Ö, Sweden; Tongren, John C., Hammermill Paper Co., Erie, Pa.; Underhay, George F., Bowaters Development and Research Ltd., Bowater House, Stratton St., London W. I., England; Van den Akker, J. A., The Institute of Paper Chemistry, Appleton, Wis.; van der Meer, W., Research Engineer, Van Gelder Zonen N. V., Research Laboratorium, Velsen (N.), Post Beverwijk, Holland; Whalen, J. F., Combined Locks Paper Co., Combined Locks, Wis.; Whitney, Roy P., The Institute of Paper Chemistry, Appleton, Wis.; Wollwage,† John C., Kimberly-Clark Corp., Neenah, Wis.; Wrist, Peter E., Quebec North Shore Paper Co., Baie Comeau, Que.

* On leave from Swedish Forest Products Research Laboratories
† Member of the Fundamental Research Committee

Symposium Members

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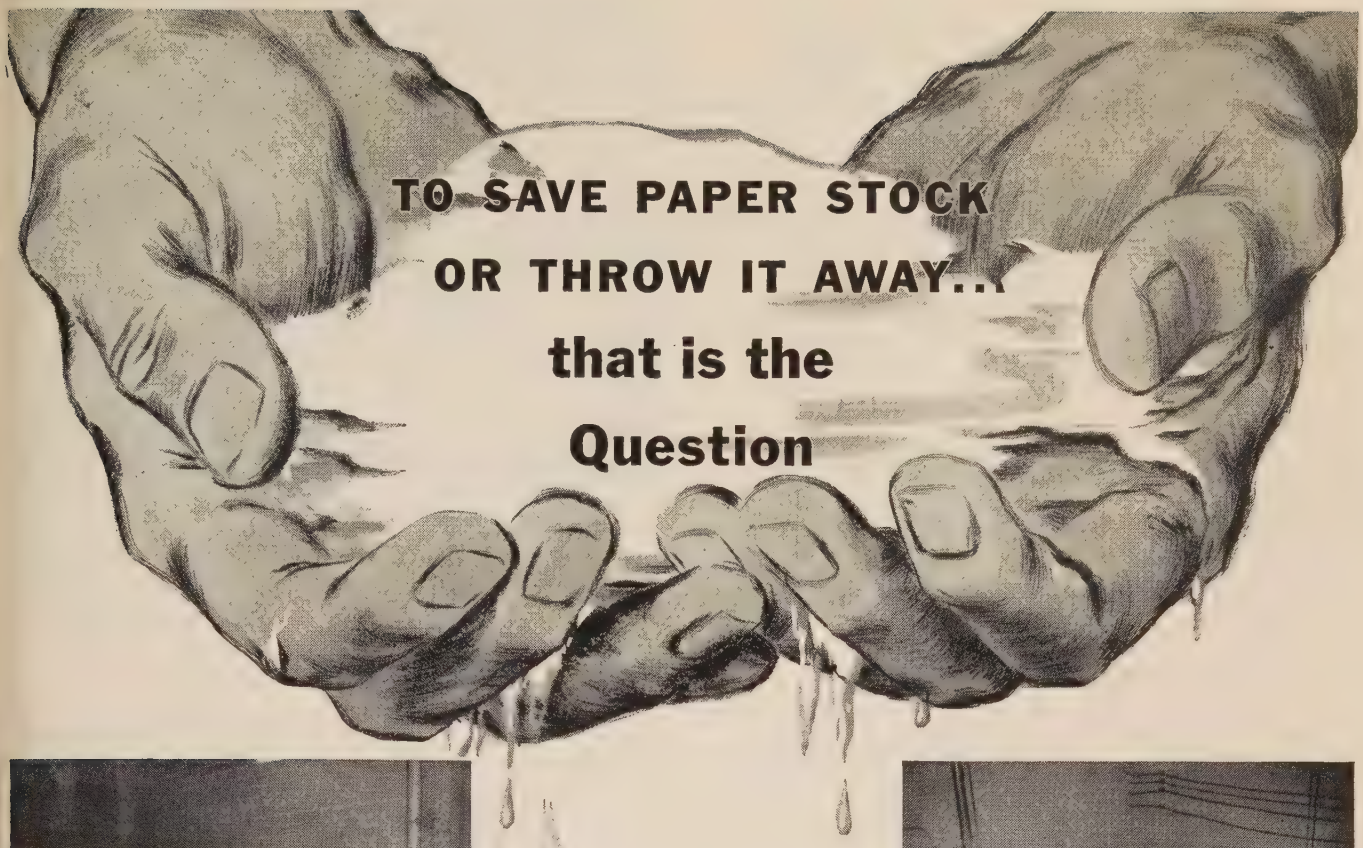
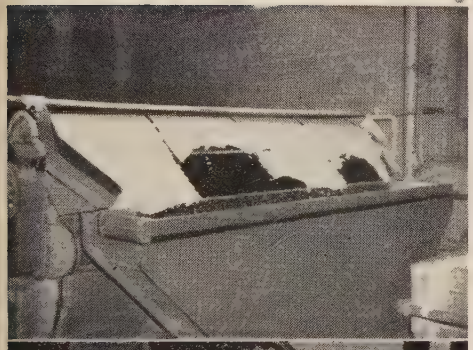
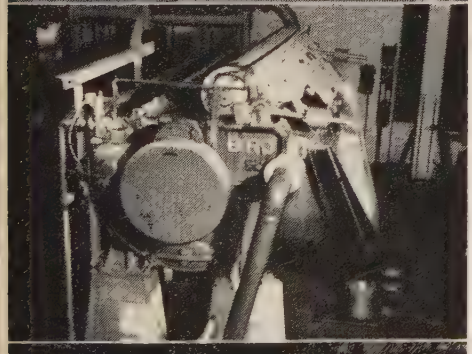


TO SAVE PAPER STOCK OR THROW IT AWAY... that is the Question





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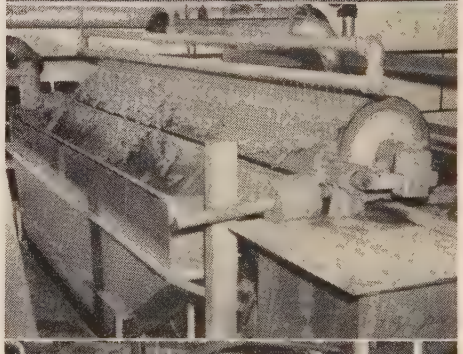

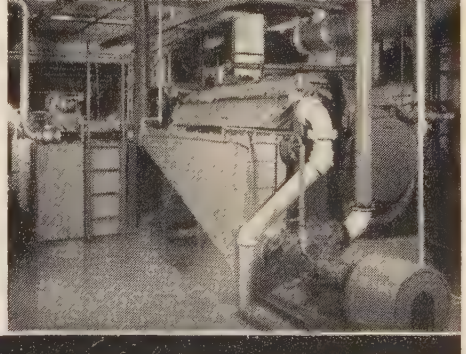

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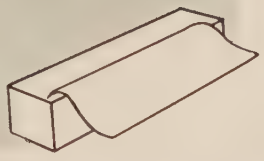

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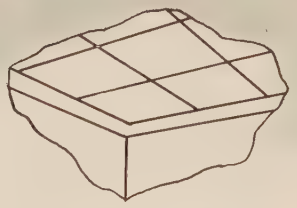

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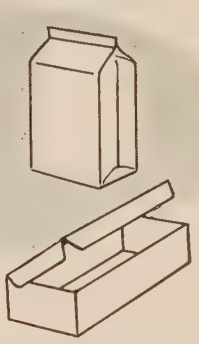

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Alkaline Pulping Conference

The Alkaline Pulping Conference was held at the Dinkler-Tutwiler Hotel, Birmingham, Ala., on Oct. 6–8, 1954. Two hundred fifty-seven men registered. Malcolm B. Pineo of the Brunswick Pulp & Paper Co., Brunswick, Ga., was chairman of the Alkaline Pulping Committee which sponsored the meeting. The technical program was organized by H. Y. Charbonnier of the Union Bag & Paper Corp., Savannah, Ga.

The local arrangements committee consisted of George L. Clark and Robert R. Fuller, co-chairmen, David A. Jones, Dimp Watkins, Philip A. Bachelder, Norman Le Maistre, Clyde Reaves, Henry Goodrich, C. L. Slaton, and Robert Kindl. R. A. Davis of the Chicago Bridge & Iron Co., and Al Clayton of the Mason-Neilan Regulator Co. were in charge of registration.

The local advisory committee consisted of A. G. Wakeman. Coosa River Newsprint Co., J. W. Warner, Gulf States Paper Co., George Rust, Rust Engineering Co., and Robert Brown, University of Alabama.

In subsequent issues of *Tappi* the papers presented at the conference and other details will be published.

The two luncheons were featured by addresses by J. W. Warner, executive vice-president of the Gulf States Paper Co. and by Boon Lert, a leprosy missionary of Thailand. The conference members were guests of the Coosa River Newsprint Co. and the Gulf States Paper Co. during a hospitality hour. The ladies attending the conference were the guests of the Rust Engineering Co. for luncheons at the Downtown Club and The Club, a tea at the Vestavia Country Club, tours of the residential section of Birmingham, Red Mountain, and the Fairfield Steel Works.

The technical program follows:

K. D. Running of the Halifax Paper Co., Roanoke Rapids,

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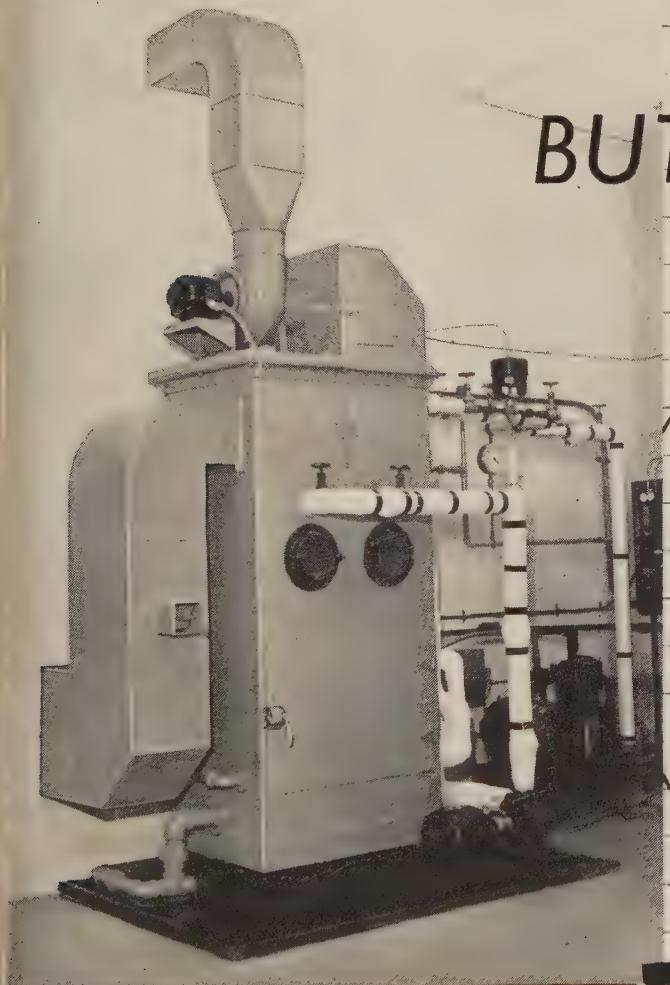

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N. C., was chairman of the Wednesday morning session. The following papers were presented:

1. "Correlation Between Lignin Content and Chlorine Number of High Yield Kraft Pulps," by E. L. Keller, Forest Products Laboratory, Madison, Wis., and Peter B. Borlew, National Container Corp., Jacksonville, Fla.
2. "Utilization of Kraft Knotter Rejects," by R. E. Millar, J. J. Owen, Jr., and J. M. Piette, Union Bag & Paper Corp., Savannah, Ga.
3. "Sulphidity in Southern Pine Kraft Pulp," by K. G. Chesley and P. L. Gilmont, The Crossett Co., Crossett, Ark.
4. "Direct vs. Indirect Cooking for Pine and Hardwood Kraft Pulps," by Owen Hunter and Hansel Wade, Brunswick Pulp & Paper Co., Brunswick, Ga.
5. "The Oxidation of Sulphate Black Liquor and Related Problems," by T. T. Collins, Jr., National Container Corp., Jacksonville, Fla.

J. McK. Limerick of the Bathurst Power & Paper Co., Ltd., Bathurst, N. B., presided at the afternoon session. The following papers were presented:

1. "Interpretation of Cooking Charts from Direct Steamed Digesters," by John Morris, Armstrong College, Savannah, Ga.
2. "Instrumentation in the Cooking Process," by Joseph F. Keyes, North Carolina Pulp Co., Plymouth, N. C.

Mr. Limerick also presided at a panel discussion dealing with "High Yield." Other members of the panel were William B. Simmons, St. Joe Paper Co., Port St. Joe, Fla.; G. H. Whiteside, Container Corp. of America, Fernandina, Fla.; David Weatherhorn, Southern Paperboard Corp., Port Wentworth, Ga.; and L. M. Sutherland, Sutherland Refiner Corp., Trenton, N. J. Among the subjects discussed were cooking, refining for high yield, washing high yield pulps, and properties and characteristics of high yield pulps.

K. G. Chesley of the Crossett Co., Crossett, Ark., presided at the Thursday morning session. The following papers were presented:

1. "Modified Permanganate Number for Partially Bleached Pulps," by Charles S. Benz, Scott Paper Co., Chester, Pa.
2. "Reuse of Knots and Shives for Bleached Kraft," by Albert L. Wiley, Riegel Carolina Corp., Acme, N. C.
3. "Instrumentation in Bleaching of Kraft Pulp," by A. P. Yundt, Camp Manufacturing Co., Franklin, Va.
4. "Preliminary Investigation of the Alkaline Pulping of Bamboo," by R. C. Sproull, Herty Foundation Laboratory, Savannah, Ga.

H. Y. Charbonnier of the Union Bag & Paper Corp., Savannah, Ga., presided at the afternoon session. The following papers were presented:

1. "Rapid Cycle Digesters," by L. E. Eberhardt, The Bauer Bros. Co., Springfield Ohio.
2. "Kraft Pulping and Bleaching of Some Southern Hardwoods," by D. J. MacLaurin and J. R. Peckham, Institute of Paper Chemistry, Appleton, Wis.

C. W. Converse of Sprout, Waldron & Co., Muncy, Pa., presided as chairman of a semichemical pulping panel. The participants and their subjects were:

W. J. Zimmerman, Parsons & Whittemore, Inc., New York, N. Y. (Wood Preparation).

K. K. Kirven, Sonoco Products Co., Hartsville, S. C. (Cooking in Rotary Digesters).

Part of the panel at the Tuesday session of the symposium, Fundamentals of the Paper Machine

W. W. Marteny, National Container Corp., Tomahawk, Wis. (Cooking in Continuous Digesters).

Joseph F. Keyes, North Carolina Pulp Co., Plymouth, N. C. (Cooking in Vertical Digesters).

C. W. Converse, Sprout, Waldron & Co., Muncy, Pa. (Refiner Feeding Systems).

J. E. Sapp, Gaylord Container Corp., Bogalusa, La. (Refining).

A. L. Wiley, Riegel Carolina Corp., Acme, N. C. (Washing).

D. J. MacLaurin, Institute of Paper Chemistry, Appleton, Wis. (Bleaching).

L. W. Murtfeldt, Consolidated Water Power & Paper Co., Wisconsin Rapids, Wis. (Corrosion in Neutral Sulphite Pulping).

On Friday inspection tours were made of the mills of the Coosa River Newsprint Co., Coosa Pines, Ala., and the Gulf States Paper Co., Tuscaloosa, Ala.

Fifth Testing Conference

The Fifth Testing Conference of the Technical Association of the Pulp and Paper Industry was held at the Hotel Biltmore, Dayton, Ohio, on Oct. 6–8, 1954. The attendance of 223 made this the largest testing conference to date. Delegates were present from 27 states, two provinces of Canada, and Finland. James P. Casey, A. E. Staley Co., Decatur, Ill., is general chairman of the sponsoring Testing Division of TAPPI.

The general chairman of the conference was C. E. Brandon, Howard Paper Mills, Dayton, Ohio. Mr. Brandon was assisted by the following committee members:

A. C. Dreshfield, Exhibits, Chicago Testing Laboratory, Chicago, Ill.

J. L. Clouse, Mill Visits, Oxford Miami Paper Co., West Carrollton, Ohio

P. A. Nussbaumer, Registration, Pollock Paper Corp., Middletown, Ohio

E. W. Petrich, Registration, Howard Paper Mills, Inc., Dayton, Ohio

G. Sieversten, Banquet, National Aluminate Corp., Dayton, Ohio

V. Perry, Banquet, Harding-Jones Paper Co., Middletown, Ohio

The technical program, which was centered around the theme "New Techniques in the Testing of Pulp and Paper and Their Raw Materials," consisted of three sessions held on October 7 and October 8. The entire day of October 6 was devoted to meetings of the various committees which

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comprise the Testing Division of TAPPI. Meetings of the following committees were held:

Microscopy—C. E. Brandon, Howard Paper Mills, Dayton, Ohio, Chairman
Pulp Testing—F. E. Caskey, Morden Machine Co., Portland, Ore, Chairman
Paper Testing—D. H. Newcomb, Riegel Paper Co., Riegel Ridge, N. J., Chairman
Container Testing—Milton Yezek, General Foods Corp.
Wax Testing—G. C. Borden, Riegel Paper Co., Hughesville, N. J., Chairman
Chemical Methods—A. S. O'Brien, Eastman Koak Co., Rochester, N. Y., Chairman
Nonfibrous Material Testing.—K. H. Williams, Mid-States Gummed Paper Co., Chicago, Ill.

The papers presented during the technical sessions are outlined briefly in the following account, and will be published in full in a future issue of *Tappi*.

Features of the conference also included the official banquet on Thursday evening, October 7, a reception at which refreshments were offered by suppliers to the industry, visits to plants in the Dayton area, and exhibits of new devices for the testing of pulp and paper and their raw materials. The official banquet was held jointly with the Ohio Section of TAPPI and with the Ohio Valley District of ASTM.

Technical Sessions

On Thursday, October 7, "Paper Testing" was the subject of the morning session, held under the chairmanship of D. H. Newcomb, chairman of the TAPPI Paper Testing Committee.

"Methods for Measuring the Stiffness of Paper" was the subject of the first paper by T. W. Lashof and R. B. Hobbs of the National Bureau of Standards, Washington, D. C. The paper was presented by Mr. Lashof, who defined stiffness as the word is applied to various "stiffness" testers, discussed several of the latter, and described their principles of operation. He described the Carson-Worthington (NBS) stiffness tester in some detail, including two recent models which extend the range of the original tester.

In the Carson-Worthington tester the specimen in the form of a rectangular strip is held at a cantilever in a vertical plane. The "clamped end" of the cantilever is caused to turn about a vertical "torque axis," and the bending moment is measured as the torque in two lengths of piano wire, between which the clamp at the clamped end is suspended. The "free end" of the cantilever is supported by a second clamp and is restrained from rotating about the torque axis but is otherwise free.

With the two new models Mr. Lashof stated that the Carson-Worthington tester is suitable for papers from light cards to tissues. He discussed some difficulties encountered in testing very weak materials and presented data from comparative tests with other methods of measuring stiffness. The author also showed illustrations of a commercial model of the Carson-Worthington stiffness tester to be manufactured by United States Testing, Inc.

The second paper was by George R. Sears of The Institute of Paper Chemistry, Appleton, Wis., who presented a "Survey of Recently Proposed Methods for Evaluating the Printability of Paper and Paperboard." In opening this discussion of printability, Mr. Sears noted the scope of the term printability and emphasized it by quoting the succinct statement of G. E. Carlsson in opening the Second International Conference of Printing Research Institutes at Stockholm in June, 1953, viz., "The printability of paper means, in fact, the suitability of paper as raw material for the printing process." Mr. Sears noted further that because of the complexity of the property of printability it is sometimes said that the only way to judge the property is to print the paper.

In a more restricted or perhaps more common sense, the printability of paper is the property which determines the quality of a print on the paper. In this regard, the methods for evaluating printability may be divided into categories, i.e. (1) the making of prints and the determination of print quality and (2) the measurement of the physical and physico-chemical properties of paper which seem to be related to printability and the attempt to correlate these results with the results of printing. The author pointed out the need of the papermaker to have the weakness and good features of his paper expressed in terms of properties over which he has some degree of control in the papermaking process. The procedure of Eckhart and Burnett (*Tappi* of August, 1953) provides an illustration of a procedure for making a print with a laboratory proof press, and determining print quality. In the second category of evaluating methods, the paper properties and smoothness, ink receptivity, and compressibility were discussed. Under smoothness, the need for quantitative means of describing the surface areas of paper which fail to come in contact with the printing form was noted during reference to the Chapman smoothness tester, the air-leak type of smoothness testers, and "printing methods" of judging smoothness of paper. Ink receptivity was considered to involve two factors: (1) the percentage of ink transferred from the form to the paper and (2) the absorption of ink and

One of the technical sessions at the Fifth Testing Conference

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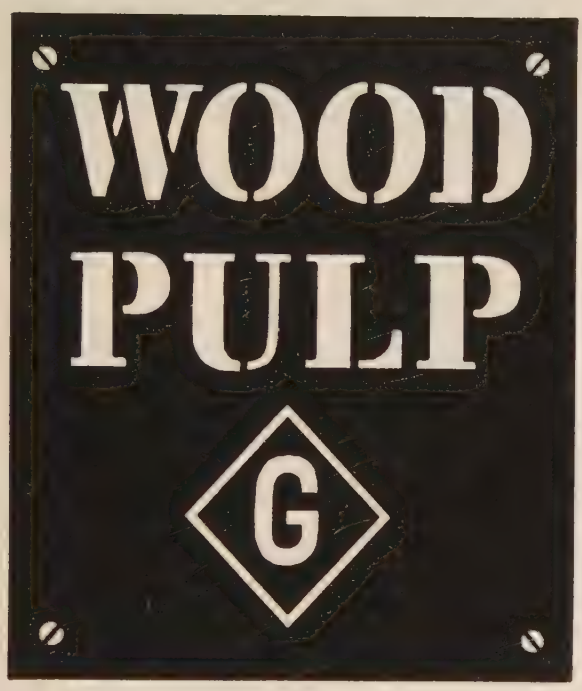

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ink fluids. Absorption includes the "instantaneous" absorption during impression and the absorption which takes place subsequently. Compressibility, softness, and resilience were discussed jointly in terms of the requirements on the dynamic behavior of paper.

Third speaker of the Thursday morning session was Richard S. Hunter of Hunter Associates Laboratory, Falls Church, Va., who discussed "New Techniques in the Optical Testing of Paper." Mr. Hunter statedth at in optical testing of papers and paper materials, progress has been fairly steady but undramatic for the past several years. Progress has been slow because of the need to combine the talents of paper technologists knowing the problems to be solved with those of optical and electronic engineers knowing the capabilities of instrumentation.

Probably the major new development in the optical line has been the Chapman smoothness tester which measures percentage area of a sheet of paper in contact with a flat glass block held against it with a pressure typical of printing-press operation. Although this new instrument was first described in 1947, its fields of application are still undergoing development.

The appearances of both printed and nonprinted papers are always complex combinations of many different factors. The experienced human eye is surprisingly agile in its ability to recognize differences in appearances and relate them to features of the ingredients and processing with which it is familiar. Instruments can usually be developed to measure specific attributes that can be seen, but the job of integrating over-all appearance seems too complex for instrumentation, even with its rapid strides of recent years.

For color measurements, at least two new instruments have been announced recently: the Colormaster Differential Colorimeter, developed at the du Pont Engineering Experiment Station, and the Davis-Bruning Colorimeter, developed at the H. B. Davis Paine Co. in Baltimore, Md. An intensive program for the development of improved methods to measure small color differences is under way in ASTM Committee D-1. When adequately standardized, these methods should find increasing use for measurements of fading and color tolerance.

In the field of gloss measurement, there are now several recorders for supercalender stacks. Under development are similar devices for even glossier waxed, lacquered, and cast-coated papers. Recently, a multiangle laboratory glossmeter was developed by the author to perform all the older gloss tests as well as the special new ones for high gloss papers. In another application of gloss measurements, the change with time of gloss of a film of oil on paper was used to rate ink permeability of the paper. Gloss is sensitive to surface condition and can doubtless be used for other analyses of surface phenomena.

E. F. Barker, Oxford Miami Paper Co.; J. J. Kelsch, Interchemical Corp.; C. E. Brandon, Howard Paper Mills; and R. P. Stoll, Eastman Kodak Co.

T. W. Lashof, National Bureau of Standards; G. R. Sears, The Institute of Paper Chemistry; R. S. Hunter, Hunter Associates Laboratory; W. J. Wilt, Sheffield Corp.; L. Nordman, Research Institute of the Finnish Pulp and Paper Industries; and D. H. Newcomb, Riegel Paper Co.

"Air Gages for Measuring the Porosity and Smoothness of Paper" was the subject of the next paper by N. Emmons and W. J. Wilt, Sheffield Corp., Dayton, Ohio. The paper was presented by Mr. Wilt, who outlined a new approach to the problems of the measurement of air resistance and smoothness of paper. The author described two new instruments both of which utilize a rotometer type of air gage known commercially as the Precisionaire. This air gage instantly indicates the rate of air flow through the gaging instrument to which it is attached, and is calibrated to give readings in units of smoothness or air permeability as the case may be.

The smoothness tester uses a steel gaging head which rests on the surface of the paper under test. The under side of the sample is supported by a piece of smooth plate glass. Low pressure air is fed into an annular groove in the head, and the air gage indicates the rate of air escapement between the surface of the paper and the gaging head. Rough papers cause a greater air flow, and consequently a higher reading on the air gage than is caused by smooth papers.

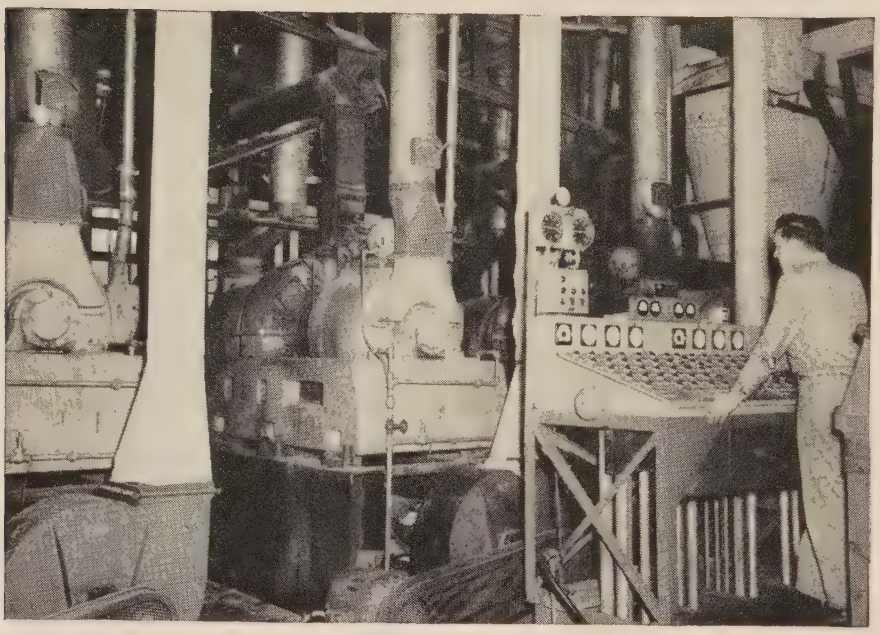
The air resistance gage known as a Porosimeter, utilizes the air gage to measure the rate of flow of air through a test sample of paper. The test sample is clamped between the gage heads by means of a quick acting fixture, and air under a pressure of 10 p.s.i. is brought against the underside of the paper. The air escapes through the paper, and through measuring orifices in the upper head.

The scales are graduated in such a manner that perfect smoothness or absolute imperviousness to air passage is shown by a zero reading, with increasing numbers indicating greater roughness or porosity as the case may be.

Both of the gages give direct and instantaneous readings, no timing being involved. The readings remain in view as long as the test sample remains in place, and the test samples may be as large as 11 by 11 in.

The final paper of the Thursday morning session was given by L. Nordman of the Research Institute of the Finnish Pulp and Paper Industries, Helsinki, Finland, who discussed "The Breaking of Bonds During the Tensile Test." Mr. Nordman had used optical methods to test the hypothesis that bonds are broken in a strip of paper subjected to strain at prerupture loads. Light scattering occurs only from the so-called free surface area of the paper. If bonds are broken

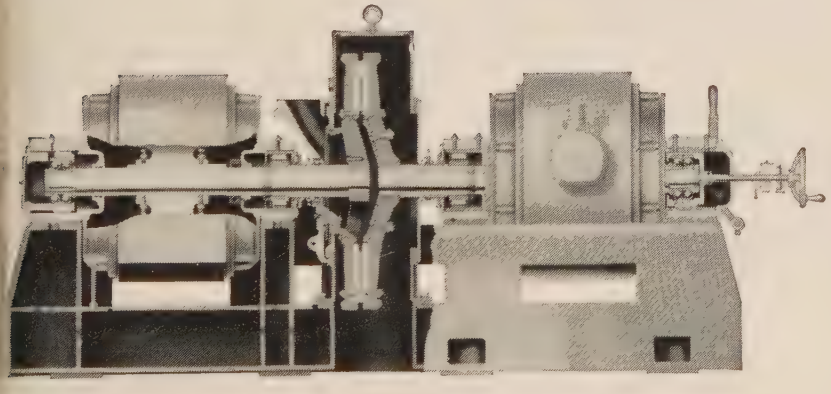
Semi-dry chips fiberized in 6 Bauer Refiners at Coos Bay Lumber Co.



Bauer

Shown in the photograph are three of the six Bauer No. 400 Refiners in the hardboard plant of Coos Bay Lumber Co., Coos Bay, Ore.

Chips from log centers and veneer trimmings are steamed for 5 to 20 minutes. From the cookers the semi-dry chips are distributed to the Bauer Refiners, each of which has two separately powered discs rotating in opposite directions.



Sectional view of Bauer No. 400 Refiner

By the action of the plates, the material is rolled, rubbed and squeezed until the fibers are separated. This tends to make the fibers more slender without being shortened, for the Bauer Refiner essentially is not a cutting machine.

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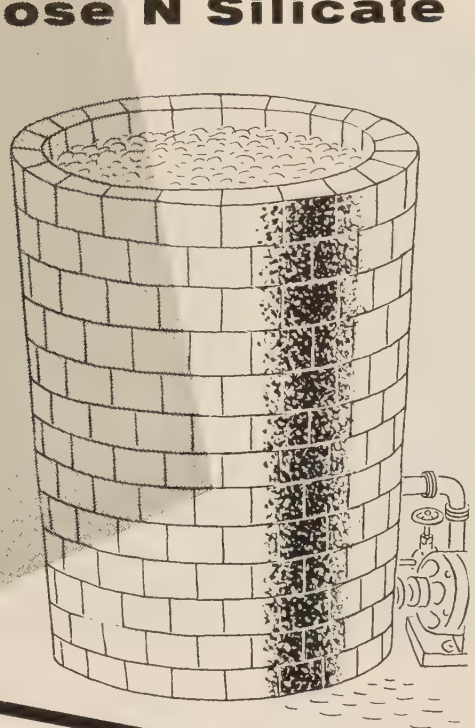

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- "Treatment of Raw and Waste Waters with PQ Silicates"... Bulletin No. 52-19
- "Stixso Adhesive Processes for Quality Corrugated Paper Board"... Bulletin No. 12-21

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in a tensile test this would lead to an increase in the free surface area of the paper and thus to an increase in light scattering. Mr. Nordman had verified this in a series of tests where paper strips were strained directly over the aperture of a sensitive reflection meter. By means of graphs representing different straining cycles Mr. Nordman showed that bonds are broken during the straining cycles and that the breaking of bonds is an irreversible process.

In relaxation tests the author found that time is a factor in the bond breaking. The rate of breaking of bonds differs in different parts of the test strip, indicating the importance of stress distribution. In quantitative tests it was found that the breaking of bonds is related to the amount of energy consumed in the straining cycle.

Mr. Nordman reported that the experimental evidence gathered supports the hypothesis that microbreaks occur all over the test strip even at prerupture loads.

Microscopy Session

The first afternoon session on Thursday, October 7, was devoted to Microscopy, under the chairmanship of C.E. Brandon, chairman of the TAPPI Microscopy Committee.

J. J. Kelsch, Interchemical Corp. Research Laboratories, New York, N. Y., presented the first paper titled "Microscopy of Ink-Paper Relationships."

Mr. Kelsch discussed methods of preparing paper samples for microscopical examination, both for cross-section work and for surface examination. The author described in detail a method of embedding in vegetable gum which is particularly applicable to very thin papers, and showed slides of the results of this method illustrating how it may be used to study ink penetration.

Describing a technique for the study of a paper surface by means of vertical dark-field illumination, Mr. Kelsch showed illustrations of the use of this technique to study ink bleed and the attitude of the ink on both coated and uncoated stock.

"Cross Sectioning of Paper Products" was the subject of the second paper by R. P. Stoll, Eastman Kodak Co., Rochester, N. Y. Mr. Stoll pointed out that cross-sectioning techniques frequently yield valuable information to a microscopist on a great variety of paper products. In addition to the classical method for cutting cross sections by embedding the sample in a paraffin block there are several other rapid procedures which can be employed to attain the same end. It is possible to use a nonembedding sectioning technique in which a paper is glued to a rigid base and then clamped in special jaws and cross-sectioned without a paraffin block.

Free hand cross sections are extremely valuable for handling

Dinner group at the Fifth Testing Conference

a variety of problems. A large number of laminated papers can be handled conveniently by this technique.

Cross sectioning is ordinarily used to obtain information on coatings and adhesive layers, or the thickness of various coatings or layers, rather than to obtain information on the stock itself. Occasionally, however, information is requested on the stock and a cross section can be cut provided the stock is first impregnated with the material to hold it together. Without an impregnating agent the cross section would disintegrate and yield no information on the stock.

When several slightly different samples are to be compared in a cross section, for example, as to the thickness of pigmented layers, it is possible to cut a sandwich cross section in which all the samples to be compared are cross sectioned in one operation. They are likewise photographed on one negative and analyzed using one print. This eliminates thickness variations as well as photographing and processing variations and permits a more nearly valid comparison of the different cross sections.

Some information can be obtained by applying various stains to a cross section, for example, starch can be readily identified in a cross section.

Micrometry is also an important phase of cross sectioning. The microscopist is frequently called upon to furnish information on the thickness of various coatings for adhesive layers. This can be done readily provided the proper equipment is available. All cross-sectioning techniques are made much more valuable if pictures can be taken and passed on to those interested. Mr. Stoll described a high-speed technique for photographing cross sections.

The third paper of the Microscopy session, "Uses of the Microscope in Paper Laboratories," by W. Landes, Paper and Pulp Testing Laboratories, New York, N. Y., was read by Ernest F. Barker, Oxford Miami Paper Co., West Carrollton, Ohio. This paper described the results of a survey made by the TAPPI Microscopy Committee to determine in what ways microscopical techniques are being used in pulp and paper laboratories. Nearly 500 responses indicated a great variety of uses of the microscope, many of them highly specialized. The typical paper laboratory has from one to three microscopes, at least one of them binocular with a mechanical stage. Many mills have an oil immersion lens, a camera, projector, and microtome. Less common accessories are micrometers and phase contrast and dark field equipment.

All paper mill laboratories use the microscope for fiber analysis and dirt and speck identification. Half the mills also use it for filler analysis and for the examination of wires, felts, and printing. Altogether, 56 different uses of the microscope were listed.

The average paper mill does not employ a full-time microscopist. Allied industries, however, are more likely to have a specially trained full-time individual for this work.

Many suggestions as to how the Microscopy Committee could help to make the microscope more valuable to the respondent were registered. The most striking feature of these was that the information desired in most cases is already available, so that it would appear that there is a need for a clearing house for information on microscopy.

Statistics Session

A brief Statistics Session, under the chairmanship of J. P. Casey, Testing Division general chairman, completed the Thursday afternoon program. C. A. Bicking, Office of the Chief of Ordnance, Dept. of the Army, Washington, D. C., presented a paper on "The Use of Statistics for Analysis of Testing Results." Mr. Bicking suggested that there are two necessary properties of a good testing method, validity and pertinence. The determination of validity, that is, the precision and accuracy of the method, is almost entirely

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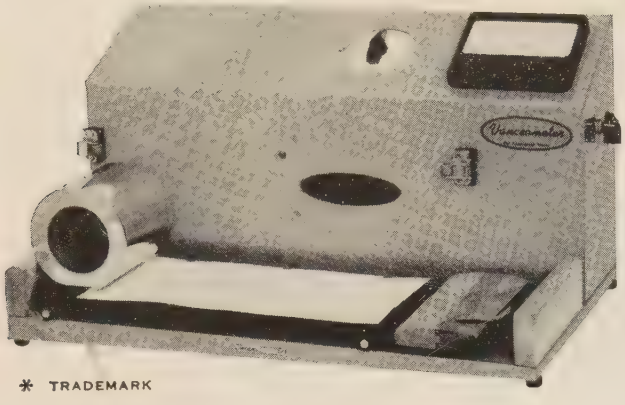

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a statistical problem. It is a relatively complex problem for pulp and paper tests because the material itself is so variable. It may never be possible to determine exactly the effect of instruments or test methods on the total variability of results.

The author described two broad approaches to the validation of testing methods. One is through the testing of a homogeneous sample in a round-robin type program. The other is the analysis of mill data obtained either from routine control testing or from special samples taken in a carefully designed program. The first approach is limited by the difficulty of finding a sufficiently uniform lot from which a random sample may be selected from each tester. The second approach is limited by the fact that unless the process is "in control" in a statistical sense, prediction on the basis of results may be extremely unreliable.

Improved testing methods and the growing awareness in the industry of the advantages of understanding the source of variability in measurement of quality, Mr. Bicking stated, justify the interest of TAPPI in the analysis of testing results. The use of modern statistical techniques has been introduced in the pulp and paper industry on a modest scale. The encouraging results in terms of economy of testing and improved definition of quality warrant a great deal more investigative work.

General Session

On Friday morning, October 8, a General Session was held under the chairmanship of W. H. Aiken, chairman of the TAPPI Container Testing Committee.

"Turbidity Number—A Measure of Pulp Additive Retention" was the title of the first paper, presented by J. S. Hickman, E. I. du Pont de Nemours & Co., Wilmington, Del.

Pointing out that analysis for the amount of light scattered by dispersing materials gives an accurate method for determining the quantity of such materials present in a water system, Mr. Hickman discussed how turbidity measurements may be used to assist the paper chemist and manufacturer in studying factors affecting the retention and efficiency of pulp additives. Stability studies with neoprene latex have been successful using the turbidity number technique and have resulted in the development of a latex dispersing system suitable for use as an additive to pulp slurries prepared from high ion content furnish water. Other problems have been studied using the technique to reduce the number of variables necessary for more extended study in large research programs. For example, a very rapid determination of the fiber area necessary for good deposition of neoprene was possible with the technique, eliminating much of the time necessary for a determination by more conventional laboratory methods. The technique has promise as a routine control test in the mill. However, experience on this aspect is still scant and it was, therefore, only possible for the author to offer some suggestions.

The second paper was titled "New Recording Fluorescence Size Tester" by K. W. Hardacker, W. A. Wink, and J. A.

At the head table during the Ohio Section—Testing Conference dinner

Van den Akker, The Institute of Paper Chemistry, Appleton, Wis. The paper was presented by Mr. Wink who briefly described the fluorescence size test which was originally described by Van den Akker, Nolan, Dreshfield, and Heller in *Paper Trade Journal* for Nov. 23, 1939. One of the outstanding features of this fluorescence size test is that the end point obtained with the Uranine B dye is determined only by the transudation of liquid water and is not influenced by the water vapor which diffuses through the sheet ahead of of the liquid water front. The recently constructed model of a recording fluorescence size tester incorporates completely automatic recording of the intensity of fluorescence versus the time function. The size time is derived from the recording in objective fashion and without dependence on operator judgment. The new instrument has greater sensitivity than the model previously described and the sensitivity is now adequate for the testing of unbleached kraft papers. Inclusion of a number of operational improvements has reduced the operating time. Arrangements for the manufacture of this instrument have not yet been made.

"The Application of Infrared and Ultraviolet Spectroscopy to Paper Problems" was the subject of the third paper of the Friday morning sessions, by A. S. O'Brien, Eastman Kodak Co., Rochester, N. Y. Infrared equipment with auxiliary tools and trained personnel represents a very large investment. Therefore its application to a branch of industry or any particular organization, Mr. O'Brien suggested, should be studied with considerable care. The most fertile field for applying infrared would be in those sections of the paper industry which use plastics and resins of various kinds. Infrared is most apt to be applied to research and development work in this field.

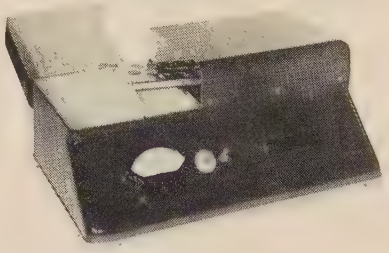
Infrared equipment is especially valuable for qualitative identification of organic compounds which are used in conjunction with sizing and converting. With the aid of infrared technique, very small quantities of pure organic compounds can be characterized. Infrared analysis, however, has definite limitations. They should be realized before large investments in equipment are considered. The author pointed out and briefly discussed some of the limitations of infrared analysis.

The interpretation of infrared curves is an extremely important part of an infrared program and close cooperation must exist between the infrared spectroscopist and those synthesizing or experimenting with the chemicals being studied, such as waxes, resins, proprietary sizes, laminants transparentizing chemicals, dimensional stabilizers, etc. In addition, a relatively complete library of curves is essential for useful application of infrared.

There are some applications of infrared analysis to the field of quantitative analysis. This branch of the science is under rapid development and expansion. A recently developed micro adapter has been applied in situations where samples are extremely limited. This technique was described by Mr. O'Brien.

At the head table during the Ohio Section—Testing Conference dinner

THE HANDLE-O-METER



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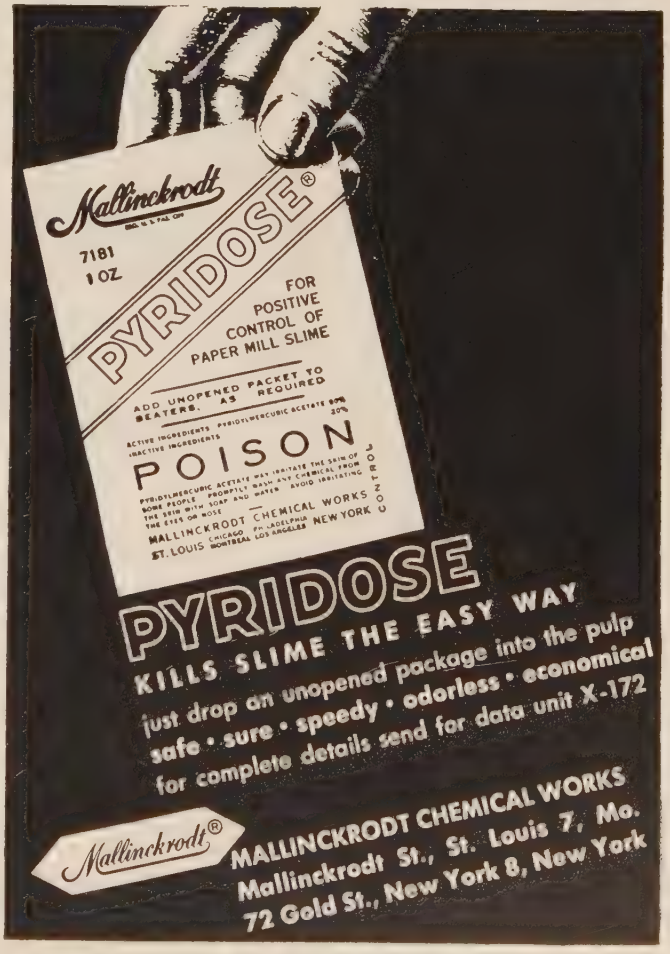
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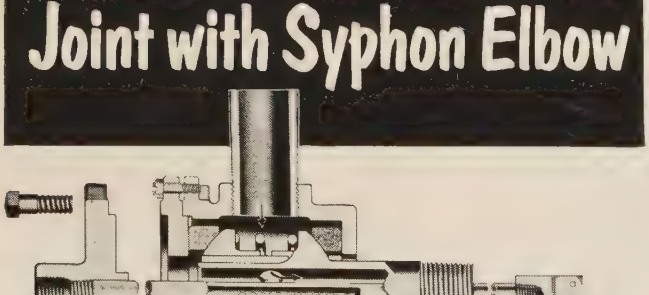

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Infrared cannot usually be directly applied to the determination of minor constituents such as 1 to 2% of an impurity in an organic compound. This limitation can be overcome by employing methods which concentrate the impurities, e.g., crystallization, chromatography, solvent extraction, etc.

Spectroscopy in the ultraviolet region also has some applications to papermaking and converting. Manual equipment is less expensive but equipment for automatic tracing of curves becomes rather costly. The number of organic compounds containing useful absorption in the ultraviolet is more limited than for the infrared region. Also, interference is, in many cases, a serious problem. However, in situations to which ultraviolet can be applied it is often extremely valuable. As opposed to infrared, ultraviolet analysis can often be applied to the determination of a minor constituent. For example, a few tenths of a per cent of a definite impurity can often be accurately measured provided it has the proper absorption and other general absorption is low. In general, ultraviolet spectroscopy is a microtechnique, and is often quantitative in nature. Ultraviolet spectroscopy is most valuable as a research and development tool, although special examples of control procedures have been developed by various companies.

The final paper of the Friday session was a discussion by Frank E. Caskey, Morden Machine Co., Portland, Ore., of "TAPPI's Proposed Standard Reference Pulp Program." Mr. Caskey stated that the fact that considerable interest has been shown by many people in the past for a standard reference pulp has led the TAPPI Pulp Testing Committee to propose a program whereby 5-lb. samples of machine-dried bleached sulphite pulp will be available to the industry for reference purposes for a nominal charge.

The author discussed possible uses for such a reference pulp, giving as example, one of many specific tests to show how the pulp could be used in connection with the comparison of the standard laboratory beater.

Banquet

On Thursday evening, October 7, the official banquet was held in the ballroom of the Dayton-Biltmore Hotel. This was a joint meeting with the Ohio Section of TAPPI and the Ohio Valley District of ASTM. The master of ceremonies was H. R. Joiner, Champion Paper and Fibre Co., chairman of the Ohio Section of TAPPI. Mr. Joiner introduced officers of the local TAPPI and ASTM groups, then called on J. P. Casey, chairman of the Testing Division, who introduced the Testing Division committee chairmen. C. E. Brandon, general conference chairman, thanked the members of the conference committee for their efforts in preparing the conference, and A. J. Winchester, of TAPPI national staff, spoke on behalf of the national organization.

At the head table during the Ohio Section—Testing Conference dinner

V. Perry, Harding-Jones Paper Co., Middletown, Ohio, introduced the speaker of the evening, Carl Ludeke of the University of Cincinnati. Mr. Ludeke delivered a most interesting informal address on "Atomic Energy Applied to Industry." Beginning with a discussion of the nuclear fission and fusion reactions involved in the atomic and hydrogen bombs, the speaker went on to consider the possible industrial applications of nuclear energy. Cost considerations make it appear likely that, within the foreseeable future, atomic piles will be used to produce power only in regions where conventional fuels are very costly due to inaccessibility.

Plant Visits

Friday afternoon, October 8, was devoted to visits to local plants of interest, including the McCall Corp., the Sheffield Corp., and the National Cash Register Co.

The gigantic printing plant of the McCall Corp. had many features of interest to the visitors, including a double-ender press capable of printing five colors on each side of a sheet running at high speed, a binder which gathers, stitches, and trims over 2,000,000 magazines daily, a shipping room in which the same number of magazines are wrapped, addressed, and mailed each day, and a pattern department where six offset presses turn out 33,000,000 dressmaking patterns annually.

At the Sheffield Corp. the visitors saw a modern plant for the manufacture of precision gages and other instruments. This company manufactures the smoothness and porosity testing instruments discussed in the paper presented by Emmons and Wilt during the Thursday morning session.

Visitors to National Cash Register Co. were guided through the company's research division, which comprises 18 laboratories working on various phases of the company's operations, including paper coating emulsions, paper coating, x-ray metallurgy, metal plating, finishing, etc.

Exhibits

Throughout the conference delegates were able to view an exhibit of recently developed testing devices for pulp and paper and their raw materials. Space was provided near the meeting rooms, and at specified hours each day the delegates had an opportunity to discuss the equipment with manufacturers' representatives.

W. M. Welch Mfg. Co., Chicago, Ill., displayed the LTF pick tester, developed recently by the Lithographic Technical Foundation, and the Densichron Reflection Densitometer, a redesigned reflection unit with improvements including better elimination of stray light and outside adjustment of the optical system. Hunter Associates Laboratory, Falls Church, Va., displayed their multiangle glossmeter, an instrument having variable reflection and field angles so that it can duplicate the angles used in any method of gloss measurement, and can measure the gloss of very high-gloss cast-coated, lacquered,

At the head table during the Ohio Section—Testing Conference dinner

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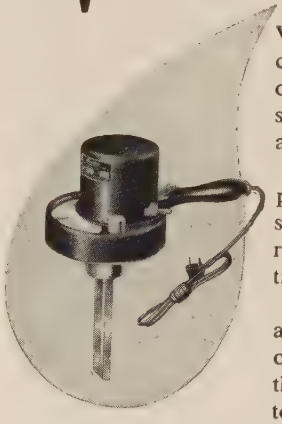

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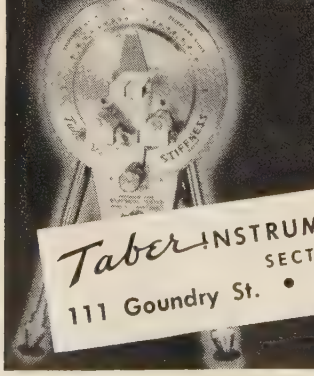

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and waxed papers. The Sheffield Porosimeter was shown in four-column and single-column models by Sheffield Corp., Dayton, Ohio. This instrument uses a rotometer-type air gage to give instantaneous porosity and smoothness readings. The Foxboro Co., Foxboro, Mass., displayed their beta ray basis weight profiler used in the paper mill to test periodic cross-machine samples, producing a strip chart showing the variations in basis weight across the machine. A table model Instron was shown by Instron Engineering Corp., Quincy, Mass. This instrument records stress-strain curves in tension or compression in load ranges from 10 g. to 100 lb., using the Instron electronic load weighing system, and is a smaller, lower-priced version of the Instron Universal Testing Instrument. The Bendix Aviation Corp., Cincinnati, Ohio, showed their Ultra-Viscoson, an electronic computer which can measure, record, and control viscosity automatically and continuously. A Macbeth Executive Skylight, which provides filtered daylight or incandescent light for color matching, and a Macbeth Munsell Disk Colorimeter were shown by the Merrifield Co., Cincinnati, Ohio, who also displayed the Macbeth-Ansco Densitometer, a photoelectric color-measuring device, and the G-5 Moisture Register for determining moisture in powdered, granular, and shredded materials. A new model Vanceometer, manufactured by Hillside Laboratories, Hillside, Ill., was exhibited by Lord & Schoenberg, Cleveland, Ohio, who also exhibited a new Hart Moisture Meter with probe knife electrodes, and one designed for measuring the moisture in a moving web. The Beckman Instrument Co. displayed a pH amplifier, flow colorimeter, gland assembly, flow chamber assembly, and a high pressure reference electrode. The flow colorimeter makes continuous measurement of the color of a flowing stream of liquid or gas, and can also be used for turbidity measurement. Central Scientific Co., Chicago, Ill., showed the Cenco moisture balance with infrared drying for rapid moisture determination, and the Cenco-Ingersoll Glarimeter for gloss of paper and other nonmetallic substances. Fisher Scientific Co., New York, N. Y., exhibited the Spectracord, a double beam continuous recording unit for D.V. type monochromators, the Davis-Bruning colorimeter, and the Fisher titrimeter for automatic titration. Testing Machines, Inc., New York, N. Y., showed a Darmstadt instrument for initial wet strength, a ply adhesion attachment for use with the Hinde and Dauch crush tester, a Gurley high pressure smoothness tester which makes tests in 4% of the normal time and permits testing one side of a single sheet, a KBB Sizing Tester which uses a galvanic circuit created between a zinc plate and a sintered bronze electrode. The Warren printing gage was shown by Precision Gage & Tool Co., Dayton, Ohio. This device is placed in the press bed and used to print an ink film of varying thickness. Hygrotester, Inc., Brooklyn, N. Y., showed the Hygrotester-Boy for the first time in the United States. This is a portable instrument for measuring moisture in a moving web.

At the head table during the Ohio Section—Testing Conference dinner

Much favorable comment was received regarding the exhibits, which provided an opportunity for testing specialists to examine and discuss the latest devices available in their field.

TAPPI Annual Meeting

The *Fortieth Annual Meeting* will take place at the Commodore Hotel, New York, N. Y., Feb. 21–24, 1955. Manuscripts of papers to be presented at the meeting should be in the hands of the Secretary by Dec. 1, 1954.

The following is a preliminary program indicating the sessions planned to date:

General Session

"Facilities for Pulp and Paper Research at Lowell Technological Institute," by John Lewis, Dept. of Paper Engineering, Lowell Technological Institute, Lowell, Mass.

"Uses of Paper in the Geodesic Pavillion," by Buckminster Fuller, Forest Hills, N. Y.

Microbiological

"Recent Developments in the Use of Chemical Treatments and Synthetic Fibers in Paper Machine Felts," by L. M. Woodside, Albany Felt Co., Albany, N. Y.

Engineering

"Basic Engineering Surveys of Steam and Electric Power Generation, Use, and Cost," by J. G. Hood, John G. Hood & Associates, Ann Arbor, Mich.

"Graphical Determination of Roll Deflection," by R. C. Sturken and D. A. Verner, Frank W. Egan Co., Bound Brook, N. J.

"Pneumatic Clutches in the Paper Mill," by J. S. Walsh, Federal Fawick Corp., Cleveland, Ohio.

"Slides of Modern Architecture in Pulp and Paper Mills," by Mario C. Celli, Celli-Flynn, McKeesport, Pa.

Deinking

"The Ahlfors Screen," by F. Schorken, Oliver United Filters, Inc., Oakland, Calif.

"The Use of the Centri-Cleaner for Cleaning Deinked Stock," by J. L. Clouse, Oxford-Miami Paper Co., West Carrollton, Ohio, and E. Rastatter, Bauer Bros., Inc., Springfield, Ohio.

"Quality Problems in Waste Paper Consumption," by Henry J. Perry, Waste Paper Utilization Council, New York, N. Y.

Semichemical Pulping

"The Liquor to Wood Ratio as a Variable in NSSC Pulping," by E. L. Keller and J. N. McGovern, Forest Products Laboratory, Madison, Wis.

"Cohesive Rating in Semichemical Pulping," by John Hart, Pulp and Paper Research Institute of Canada, Montreal Que.

"The Recovery of Waste Liquors from NSCC Pulping by the Sulfox Process," by A. Pollak and R. S. Aries, Sulfox Corp., New York, N. Y.

"A Comparison of the Action of Sodium and Sodium Neutral Sulphite Liquors on Wood Mead," by D. J. MacLaurin, J. E. Stone, and C. Förderreuther, The Institute of Paper Chemistry, Appleton, Wis.

Cylinder Board

"Vat Exhauster Survey," by Otis Whitworth, Black-Clawson Co., Hamilton, Ohio.

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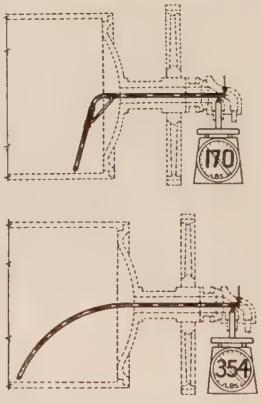

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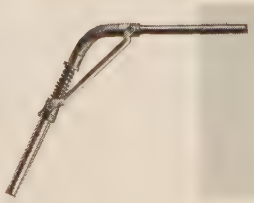

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"Development of the Shartle Alligator Refiner," by H. P. Espenmiller, Black-Clawson Co., Middletown, Ohio.

WATER

"Chemical and Biochemical Effluent Treatment," by E. Farber and D. V. Robertson, Timber Engineering Co., Washington, D. C.

FUNDAMENTAL RESEARCH

ACID PULPING

DISSOLVING PULP

"The Relationship of Tire Cord Properties to the Amount of Beta-Cellulose and Resistant Pentosan in the Pulp," by D. D. Bachlott, E. I. du Pont de Nemours, Inc., Wilmington, Del.

"Carbohydrate Components of Prehydrolysis—Sulphate Pulps from Sweet Gum and Loblolly Pine," R. L. Mitchell and J. F. Saeman, Forest Products Laboratory, Madison, Wis.

"A Method of Qualifying Dissolving Grade Pulps," by B. G. Hoos, Brown Co., Berlin, N. H.

CORRUGATED CONTAINERS

"Variable Speed Drive—Principal Advantages and Disadvantages," by Samuel M. Langston Co., Camden, N. J.

"Moisture Control at the Corrugator—Warp Control by Instrumentation on the Double Backer," by D. Ellinger, Downing Box Co., Milwaukee, Wis.

"Résumé of Printer-Slotter Questionnaire," by D. P. McNelly, Fort Wayne Corrugated Paper Co., Fort Wayne, Ind.

"Printing Die Practices on the Printer-Slotter," by A. Schmidt, Commercial Stamping Co., Chicago, Ill.

"Research Project into Machine Design for New Corrugator," by W. Ward, F. X. Hooper Co., Glenarn, Md.

"Quality Control of Raw Materials," by Ked Martin, Fort Wayne Corrugated Paper Co., Fort Wayne, Ind.

"Score Profiler," by R. C. McKee, The Institute of Paper Chemistry, Appleton, Wis.

STATISTICS

DIGESTER CORROSION

FINISHING AND CONVERTING

"A New Concept in Roll Wrapping," by C. S. Adams, Rice Barton Corp., Worcester, Mass.

"Warehousing, Shipping, and Materials Handling of Carton Packed Papers," by S. W. Blanchard, Mead Corp., Chillicothe, Ohio.

"Remote Control Edge Alignment," by H. G. Weber & Co., Kiel, Wis.

CHEMICAL ENGINEERING

PATENTS

"Patent Office Practice," by Frank Makara, 233 Broadway, New York, N. Y.

"Recent Court Decisions," by Frank Makara, 233 Broadway, New York, N. Y.

FOURDRINIER

"Dimensional Stabilization of Paper," by H. Ericks, The Upson Co., Lockport, N. Y.

PLASTICS

"Report on the TAPPI WVP Research Project," by V. Stannett, College of Forestry, Syracuse, N. Y.

"A Motion Picture Investigation of Polymer Latex Phenomena," J. W. Vanderhoff, Dow Chemical Co., Midland, Mich.

ALKALINE PULPING

"Technical Data and Operating Figures from the Most Recent Kamyr Continuous Cooking Plants," by J. Richter, Kamyr, Inc., Hudson Falls, N. Y.

"Effect of Jack Pine Pulpwood Storage on Sulphate Pulp Yield and Quality," by J. S. Martin and J. N. McGovern, Forest Products Laboratory, Madison, Wis.

"The Use of Chemicals in Improving Southern Pine Timber Stands," by A. E. Griffiths, Ethyl Corp., New York, N. Y.

GRAPHIC ARTS

PULP PURIFICATION

"Chlorine Dioxide and Safety," by J. F. Haller and W. W. Northgraves, Olin-Mathieson Chemical Corp., Niagara Falls, N. Y.

PREPARATION OF PAPERMAKING MATERIALS

"Beater Addition Resins," College of Forestry, Syracuse, N. Y.

"Electrokinetics of Rosin Size," University of Maine, Orono, Me.

"The Deculator-Cleaner," by J. C. Stewart and J. A. Smith, Rotareaed Corp., Bronxville, N. Y.

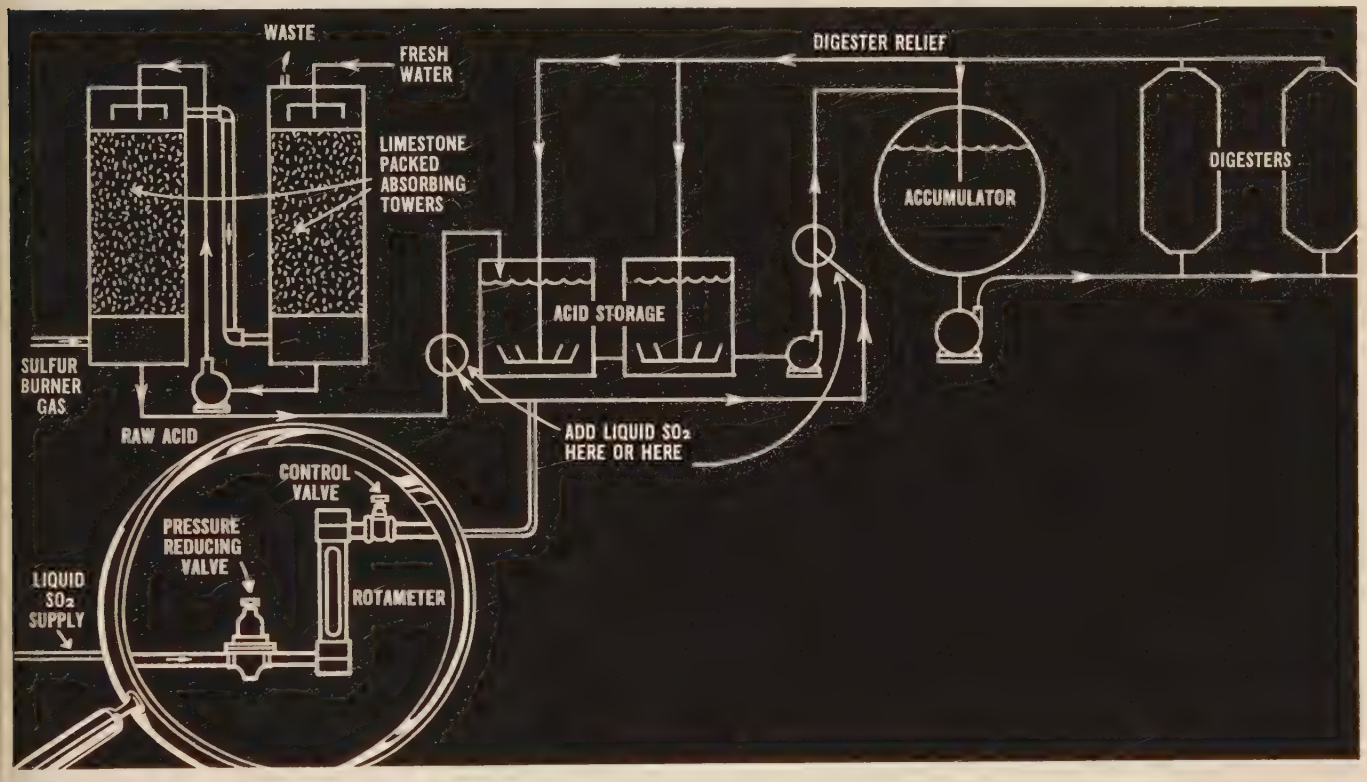
TESTING

"The Analysis of Fillers in Paper by Spectrographic Methods," by L. Block and John Lewis, Lowell Technological Institute, Lowell, Mass.

"Chlorides in Paper," Eastman Kodak Co., Rochester, N. Y.

SULFITE MILL OPERATORS:

cut cooking time improve quality



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PERSONAL MENTION

Items About New and Old Tappimen

New TAPPI Members

Wallace M. Ackerman, Control Laboratory Supervisor, West Virginia Pulp & Paper Co., Charleston, S. C., a 1941 graduate of Clemson A & M College.

Preston T. Bankston, Technical Director, Georgia Coating Clay Co., Macon, Ga., a 1953 graduate of Georgia Institute of Technology with a Ph.D. degree.

Stanley A. Bobe, Engineering Supervisor, Westinghouse Electric Corp., Atlanta, Ga., a 1927 graduate of Washington State College.

Robert L. Boehm, Research Chemist, The Mead Corp., Chillicothe, Ohio, a 1948 graduate of Colgate University.

Waldemar Borgest, Chief Engineer, Industrias do Papel Simao S/A, Sao Paulo, Brazil, a graduate of Far East Politecnical Institute.

Charles L. Brown, Assistant Technical Service Director, Crossett Paper Mills, Crossett, Ark., a 1951 graduate of Georgia Institute of Technology.

Frederick C. Came, Industrial Engineer, Box Div., Union Bag & Paper Corp., Savannah, Ga., a 1941 graduate of Massachusetts Institute of Technology.

Donald A. Charleson, Project Engineer, Crown Zellerbach Canada Ltd., Ocean Falls, B. C., Canada, a 1949 graduate of the University of British Columbia.

Marshall J. Charlton, Quality Control Manager, Krafco Container Corp., West Monroe, La. Attended Tulane University.

John G. Copeland, Junior Industrial Engineer, National Container Corp., Mill Div., Valdosta, Ga., a 1948 graduate of Florida State University.

William T. Creson, Project Engineer, The Ohio Boxboard Co., Rittman, Ohio, a 1950 graduate of Purdue University.

John K. Ferguson, Assistant to the Executive Vice-President, St. Regis Paper Co., New York, N. Y. Attended Syracuse University.

Robert R. Ferguson, Resident Manager, Crown Zellerbach Canada Ltd., Ocean Falls, B. C., Canada. Attended the University of Arizona.

Floyd L. Fitts, Superintendent, Standards Section, E. I. du Pont de Nemours & Co., Inc., Martinsburg, W. Va., a 1940 graduate of Colby College.

Fred H. Freuler, Project Engineer, West Virginia Pulp & Paper Co., New York, N. Y., a 1945 graduate of the Institute of Technology, Winterthur, Switzerland.

Fred J. Gedemer, Engineer, Nekoosa Foundry & Machine Works, Inc., Nekoosa, Wis., a 1949 graduate of Marquette University.

Herbert A. Habiger, Project Engineer, Karton fabrik Franz Mayr-Melnhof & Co., Vienna, Austria, a 1951 graduate of the Technical University, Vienna.

Norman D. Hanson, Laminating Specialist, Bakelite Co. Div., Union Carbide & Carbon Co., Bloomfield, N. J., a 1923 graduate of Michigan College of Mines.

James D. Hickel, Sales Engineer, A. E. Ehrke & Co., Cleveland, Ohio, a 1947 graduate of Ohio State University.

John E. Hoeft, Engineer, National Container Corp. of Wisconsin, Tomahawk, Wis., a 1941 graduate of the University of Wisconsin.

Robert S. Howard, Process Engineer, Wausau Paper Mills Co., Brokaw, Wis., a 1946 graduate of Marquette University.

Robert J. Hower, Sales Representative, Allis-Chalmers Mfg. Co., Inc., Milwaukee, Wis., a 1936 graduate of New York University College of Engineering.

Donald V. Hyzer, Mechanical Engineer, American Box Board Co., Filer City, Mich., a 1946 graduate of the University of Wisconsin.

Olli Karjarlainen, Engineer, Oulu Oy, Oulu, Finland, a 1949 graduate of the Technical College of Tampere.

Russell B. Keeney, Test Manager, International Business Machines Corp., Endicott, N. Y.

Horace Keesey, III, Trainee, Schmidt & Ault Paper Co., York, Pa., a 1951 graduate of Lafayette College.

W. James E. Kirk, Research Chemist, Minnesota & Ontario Paper Co., Minneapolis, Minn., a 1950 graduate of Queens University.

William O. Kroeschell, Assistant Technical Director, Michigan Carton Co., Battle Creek, Mich., a 1951 graduate of The Institute of Paper Chemistry.

Gunnar N. E. Krogh, Engineer, Sao Paulo, Brazil, a 1935 graduate of Royal Technical University, Stockholm.

George S. Lee, Sr., Chemist, Hollingsworth & Whitney Co., Chickasaw, Ala., a 1949 graduate of Spring Hill College.

Clarence W. Linebaugh, Superintendent, Schmidt & Ault Paper Co., York, Pa.

Livio G. Kuhl, Engineer, Acacia S.A.C.é I., Buenos Aires, Argentina, a 1950 graduate of Universidad de Buenos Aires.

Otto Kunnemeyer, Jr., Laboratory, Gebr. Kunnemeyer, Horn/Lippe, Germany, a graduate of the University of Hamburg.

George Lambe, Chemist, The Gardner Board & Carton Co., Middletown, Ohio, a 1954 graduate of the New York State College of Forestry.

Richard W. Loheed, Div. Manager, Dairypak, Inc., Cleveland, Ohio, a 1937 graduate of Norwich College.

Charles R. Lombard, Jr., Service Engineer, E. I. du Pont de Nemours & Co., Inc., Wilmington, Del., a 1949 graduate of the University of Maine.

John C. Mahaley, Chemist, Hammermill Paper Co., Erie, Pa., a 1951 graduate of Dickinson College.

Ronald C. Mallach, Superintendent, American Writing Paper Corp., Holyoke, Mass., a 1935 graduate of the University of Massachusetts.

John L. McClintock, Jr., Chief Chemist, Weyerhaeuser Timber Co., Pulp Div., Longview, Wash., a 1948 graduate of Oregon State College.

Ernest F. McIntyre, Vice-President and General Manager, McIntyre Bros. Paper Co., Inc., Fayetteville, N. Y., a 1926 graduate of New York State College of Forestry.

Leo J. Meyer, Supervisor of Material Standards, The Gardner Board & Carton Co., Middletown, Ohio.

John S. Mudgett, Assistant Chief Engineer, Strathmore Paper Co., West Springfield, Mass., a 1938 graduate of Worcester Polytechnic Institute.

John O. Mullen, Project Engineer, The American Paper Goods Co., Kensington, Conn., a 1940 graduate of Yale University.

William Nagorny, Assistant Engineer, Schmidt & Ault Paper Co., York, Pa., a 1950 graduate of Pennsylvania State College.

Francis X. Nerney, Sales Service Representative, Becco Sales Corp., Buffalo, N. Y., a 1937 graduate of Lowell Technological Institute.

William L. Nieland, Assistant Director, Engineering Div.,

W. H. & L. D. Betz, Chicago, Ill., a 1940 graduate of Drexel Institute.

Robert T. Olsen, Fiber Technologist, The Celotex Corp., Marrero, La., a 1942 graduate of Massachusetts Institute of Technology with a Ph.D. degree.

Richard W. Pettersen, Director, Research and Promotion, St. Paul & Tacoma Lumber Co., a 1950 graduate of the College of Forestry, University of Washington.

Alexander M. Phillips, Managing Director, Sternberg & Phillips Ltd., London, England, a 1912 graduate of the City of London College.

Rudolf A. V. Raff, Manager of Technical Development, Koppers Co., Inc., Pittsburgh, Pa., a 1932 graduate of the University of Vienna with a PH.D. degree.

Howard W. Rowan, Jr., Plant Engineer, Sitroux, Inc., New Hartford, N. Y., a 1949 graduate of Stevens Institute of Technology.

Joseph F. Russell, Technical Librarian, Kaiser Engineers Div., Henry J. Kaiser Co., Oakland, Calif., a 1908 graduate of De LaSalle Institute.

Edward Salavee, Master Mechanic, Industries do Papel Simao S/A, Sao Paulo, Brazil.

George H. Saunders, Research Chemical Engineer, Kimberly-Clark Corp., Neenah, Wis., a 1939 graduate of Michigan College of Mining & Technology.

J. Blair Scott, Sales Engineer, Pandia, Inc., New York, N. Y., a 1945 graduate of Queens University.

William A. Springer, Plant Manager, Alpha Cellulose Corp., Normal, Ill.

U. G. Stoeffler, Assistant Superintendent, Allied Paper Mills, Kalamazoo, Mich., a 1944 graduate of the University of Michigan.

Charles L. Stumpp, Product Development Engineer, West Virginia Pulp & Paper Co., Covington, Va., a 1936 graduate of Cooper Union, New York, N. Y.

Juan Swoboda, Managing Director, Juan Swoboda, Inc., New York, N. Y., a 1930 graduate of University of Vienna Law School, with a Dr.jur. degree.

Robert V. Touchette, Student, University of Maine, Orono, Me.

James M. Tucker, Project Engineer, Buckeye Cotton Oil Co., Cellulose Div., Memphis, Tenn., a 1947 graduate of Georgia Institute of Technology.

William S. Tuttle, Partner, Tuttle Law Print, Rutland, Vt.

Hans E. Unander-Scharia, Plant Project Engineer, The Ruberoid Co., Gloucester City, N. J., a 1944 graduate of the Institute of Technology, Stockholm.

Alden D. White, Assistant Chief Mechanical Engineer, Stone & Webster Engineering Corp., Boston, Mass., a 1929 graduate of Cornell University.

Fillmore G. Wilson, Design Engineer, J. E. Sirrine Co., Greenville, S. C., a 1937 graduate of Washington & Lee University.

TAPPI Notes

O. P. Aggaruala, formerly of the Crown Zellerbach Corp., is now a Graduate Student at the University of Maine, Orono, Me.

George J. Ahlquist, formerly of the National Container Corp. of Wisconsin, is now in the Control Dept. of Longview Fibre Co., Longview, Wash.

Gordon F. Allo, Superintendent of Control for the Bathurst Power & Paper Co., has been transferred from Bathurst, N. B., to Montreal, P. Q.

William C. Atkins of Dowell, Inc. has been transferred from Charlotte, N. C., to Houston, Tex., as Area Manager.

W. Gordon Baker, formerly of the Brompton Pulp & Paper Co., is now General Superintendent of the St. Lawrence Corp., Red Rock, Ont.

Paul W. Bartholomew is now Technical Director of the Paper and Insulite Div. of the Minnesota & Ontario Paper Co., International Falls, Minn.

George D. Bearce, formerly Vice-President and General Manager for the St. Regis Paper Co., is retired and is a Consultant on Pulp and Paper Projects in Bucksport, Me.

J. Edmund Becker, formerly of the Alton Boxboard Co., is now Production Manager for the J. P. Lewis Co., Beaver Falls, N. Y.

Edgar G. Boyce, Technical Service Representative for E. I. du Pont de Nemours & Co., Inc., has been transferred from Wilmington, Del., to New York, City.

Arthur M. Brooks, formerly of the Raffold Corp. of America, is now a consultant for Columbia-Southern Chemical Corp., Pittsburgh, Pa.

James D. Brown, Sales Engineer for the Sutherland Refiner Corp., has been transferred from Montreal, P. Q., to Trenton, N. J.

Peter Calott, formerly of the American Cyanamid Co., is now Process Engineer of the Wausau Paper Mills Co., Brokaw, Wis.

Robert F. Caswell, Jr., Chemical Engineer for the St. Regis Paper Co., Deferiet, N. Y., is now in the U. S. Army.

Alfred J. Corey is now Chief Chemist of Braser Co., Ltd., Edmundston, N. B., Canada.

Eldon Cronquist, formerly Plant Manager of the Ashtabula Corrugated Box Co., is now with the Inland Container Corp., Indianapolis, Inc.

Lovell M. Cushing, formerly of the Brown Co., is now Technical Director of the North Carolina Pulp Co., Plymouth, N. C.

William Daniels, formerly of the American Coating Mills, is now an Engineer with The Ohio Boxboard Co., Rittman, Ohio.

Dan S. Edgerton, formerly a Student at the University of Maine is now in the Technical Control Dept., Rogers Fibre Co., Inc., Bar Mills, Me.

Harry P. Eichin, Engineer for the Visking Corp., has been transferred from Little Rock, Ark., to Chicago, Ill.

Vernon H. Emory is now Manager of Manufacturing of Pulp and Paperboard for the Fraser Cos., Ltd., and Restigouche Co., Ltd., Edmundston, N. B.

A. E. H. Fair, formerly President of the Alliance Paper Mills, is now Executive Vice-President of the Brown Co., Boston, Mass.

Samuel H. Greenwood, formerly of Flynn & Emrich Co., is now Treasurer and Salesman for Greenwood Engineering Co., Inc., Baltimore, Md.

Harold L. Field, formerly of the West Virginia Pulp & Paper Co., is now Chemist for the Deerfield Glassine Co., Monroe Bridge, Mass.

Gilbert Heath is now Vice-President in Charge of Production of the Scott Paper Co., Chester, Pa.

Ernest K. Jamieson is now Vice-President and Manager of the Huffman-Wolfe Southern Corp., Atlanta, Ga.

Gerald G. Johnston is now Manager of the Folding Boxboard Mill Div. of Waldorf Paper Products Co., St. Paul, Minn.

W. A. Ketchen is now Technical Director of Fraser Co., Ltd., Edmundston, N. B., Canada.

John H. Kuhn, formerly of the Lowe Paper Co., is now a Graduate Student at the New York State College of Forestry, Syracuse, N. Y.

William M. Lehmkuhl, Consultant, has moved his office from New York City to Pontchartrain Hotel, New Orleans, La.

Frank W. Lorey, formerly of The Mead Corp., is now Assistant Professor and Pilot-Plant Group Leader at the College of Forestry, State University of New York, Syracuse, N. Y.

Albert T. Maasburg is now Technical Director of the Cellulose Products Div., Dow Chemical Co., Midland, Mich.

Robert I. Mason, Service Engineer for the Hercules Powder Co., has been transferred from Holyoke, Mass., to Burlington, Ont.

James W. McCrum, formerly of Tasmanian Board Mills, Ltd., is now Technical Assistant to the Managing Director of Ernest Nelson Ptg., Ltd., Melbourne, Australia.

Gordon J. Morrisette, formerly of the St. Anne Paper Co., Ltd., is now Mill Manager of Abitibi Power & Paper Co., Ltd., Iroquois Falls, Ont.

Gordon Morsett, formerly of the Detroit Sulphite Pulp & Paper Co., is now with the Rochester Paper Co., Rochester, Mich.

Frank E. Newton, Manager of the Robert Gair Co., Ohio Corrugated Box Div., has been transferred to the Philadelphia, Pa., Corrugated Box Div. as Manager.

Norman H. Nuttall, formerly of Stein, Hall & Co., is now a Special Technical Representative for the Hubinger Co., Keokuk, Iowa.

Robert S. Painter, formerly of the Celanese Corp. of America, is now a Chemist for the International Paper Co., Glens Falls, N. Y.

Stanley J. Pasternak is now Development Engineer for the H & V Specialties Co., Inc., East Walpole, Mass.

Carl D. Perkins is now Chemical Engineer for the St. Regis Paper Co., Bucksport, Me.

Leonard A. Pierce, Jr., formerly of the St. Regis Paper Co., has been transferred from Kalamazoo, Mich., to New York City as Assistant to the Vice-President.

Michael Pope has opened an office at 101 Park Ave., New York, N. Y., as Consulting Engineer on Steam and Electrical Problems.

Richard A. Premo is now Assistant Mill Manager of the Gould Paper Co., Lyons Falls, N. Y.

Charles S. Russell is now Superintendent of the Coating Dept., Central Paper Div., Muskegon, Mich.

Homer P. St. Clair, formerly of the French Paper Co., is now Superintendent of the Beverly Mills Co., Gary, Ind.

W. H. Schlafge is now General Manager of the International Falls, Minn., Div. of the Minnesota & Ontario Paper Co.

Bruce W. Smith is now Sales Manager of the Instrument Div. of Isotope Products, Inc., Buffalo, N. Y.

James G. Sylvester, formerly of the Mutual Boiler & Insurance Co., is now a Consulting Engineer in South Weymouth, Mass.

Arthur Tournas, formerly Student at the Lowell Technological Institute, is now a Student and Instructor in the Dept. of Chemical Engineering, University of Maine, Orono, Me.

Carola Trittin is now Technical Director of the Ward Paper Co., Merrill, Wis.

V. J. Westbrook is now Supervisor of all of the pulp mills of the St. Regis Paper Co., Pensacola, Fla.

Donald A. Yateman, formerly of the Army Chemical Center in Maryland, is now Paper Supervisor for the Dixie Cup Co., Easton, Pa.

Robert N. Zabe, formerly of the Champion Paper & Fibre Co., is now Associate Professor in the Paper Technology Dept., Western Michigan College, Kalamazoo, Mich.

H. W. Zussman, formerly Sales Manager for the Alrose Chemical Co., Div. of Geigy Chemical Corp., Providence, R. I., is now Sales Manager for Geigy Industrial Chemicals Div., New York, N. Y.

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Peter J. Schweitzer, Inc. has removed its executive offices from the Chrysler Bldg. to 261 Madison Ave., New York, N. Y.

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H. M. Pier, Sales Manager for the Research Corp., has moved his office from Chicago, Ill., to Bound Brook, N. J.

* * *

John R. Dufford, Assistant General Manager, has succeeded *Richard T. Anderson*, deceased, as the official representative of the Paterson Parchment Paper Co., Bristol, Pa., in the Technical Association.

Industry Notes

PRODUCTION

In July, as a result of mill shutdowns for vacations and general repair work, the output of paper and paperboard decreased about 10% from the June level to an estimated 2,052,000 tons, comprised of 1,043,000 tons of building and paperboard and 1,009,000 tons of paper.

The production of printing papers, exclusive of newsprint, moved downward as an estimated 268,000 tons were manufactured during the month. This was approximately 10% less than in the preceding month when almost 300,000 tons were made and about 4% less than in July of last year. Since the beginning of the year, production and new orders for these papers have been in balance, each averaging approximately 297,000 tons. Shipments, however, have averaged slightly in excess of 298,000 tons per month, causing the backlog of unshipped orders to decrease by about 9000 tons since January to the present level of 283,000 tons.

The July output of fine papers, also reflecting mill vacation and repair policies, amounted to 95,000 tons. The decrease of 16% from the June level was consistent with the decrease that occurred in July of last year. The volume of orders received exceeded shipments, which were in line with production, causing the backlog of orders on hand to rise to 64,000, their highest level since September, 1953, when they amounted to 70,000 tons, and 12% higher than the monthly average for the first six months of this year.

Production of coarse papers, estimated to have been about 262,000 tons, was 9% less than in June but was 3% more than in July of last year. New orders for the month at 275,000 tons continued at a level in line with that of recent months and, because curtailed shipments amounted to only 260,000 tons, the backlog of orders for this group of papers rose to 125,000 tons. Despite this improvement, however, the order backlog was about 10% less than at the same time last year.

The manufacture of tissue paper, which has been proceeding at a record pace throughout the year, continued to do so in July as 136,000 tons, about 3% more than in June, were produced. Thus, for the first seven months of the year production of these papers has been at a rate which, if continued for the balance of the year, would result in an output of approximately 1,600,000 tons.

The paperboard segment of the industry continued to demonstrate improved stability in July as 915,000 tons were produced and the June to July decrease, as in the instance of 1953, amounted to about 11%. The volume of unfilled orders rose during the month to 380,000 tons, the highest level since March, and was equal to eleven days of production.

New uses of paper connected with vacation time have helped to offset the Summer slackness which used to be a characteristic of the paper industry. Included among the newer products are: beach sandals, shoe cleaning "cloths," shower and bath mats, face "cloths," new types of fruit and vegetable packages, and carry-home packages for beverages.

In general, the demand for paper and paperboard this year has been better than the most hopeful expectations at the turn of the year. Inventories were reduced during the first several months of the year and were reported at satisfactory levels at midsummer. Increased competition placed greater emphasis on improved quality and better service, but prices remained steady. The need for improved quality is reflected in an extensive modernization program throughout the industry.

Labor relations have continued generally harmonious, the only point of conflict being the logging strike in the Pacific

Northwest, which had not affected mill operations to any degree up to mid-August.

While wood pulp consumption showed little change from the first half of 1953, wastepaper consumption declined 7% pointing to the fact that under more competitive conditions there is a tendency to produce a higher proportion of paper and paperboard from virgin pulp.

Imports

The value of imports of papermaking raw materials, paper, paperboard, and paper products for the first half of 1954 and 1953, as reported in the monthly FT 110 reports of the Bureau of the Census for 1954 and 1953, is as follows:

	1954 (P)	*1953*	*Per cent change*
Grand Total	$450,288,171	Not available	..
Paper base stocks	993,400	Not available	..
Paper manufactures	522,820	Not available	..
Total	448,771,951	460,214,276	−2
Pulpwood	14,168,806	13,082,673	+8
Wood pulp	122,057,856	134,667,445	−9
Rags, bags, grasses, etc.	1,924,001[a]	2,301,494	−16
Paper	299,334,420[a]	297,945,665[b]	..
Paperboard	5,679,940	7,616,106	−25
Paper products	5,606,928	4,600,893	+22

(P) Preliminary.
[a] Includes newsprint at $292,184,035.
[b] Includes newsprint at $290,844,002.

Pulpwood

For the first half of this year, pulpwood receipts totaled 13,401,000 cords, 307,000 cords more than in the first half of last year. Both domestic receipts and imports increased, the former 253,000 cords and the latter 54,000 cords. Decreases of 1% in the volume of receipts were reported by mills in both the Appalachian and Southern Regions, the other three regions showing increases ranging from 2 to 15%.

The consumption of pulpwood has been maintained at a high level amounting to 14,346,000 cords for the first half of 1954. This was an increase of 278,000 cords over the comparable period last year. Regionally, the Northeast and the Lake States registered declines of 1 and 4%, respectively. Increases of 1% were reported for both the Appalachian and Southern Regions, while the Pacific Northwest showed a 13% gain.

Wood Pulp

Wood pulp production continued at a high level during June and for the first six months of this year totaled 8,973,000 tons, an increase of 191,000 tons over the comparable half-year period last year.

In line with continuing high paper production, wood pulp consumption in June of 1,606,000 tons was the third highest on record, bringing total consumption for the first half of this year to 9,390,000 tons, an increase of 40,000 tons over the comparative period in 1953.

Imports from abroad continued to lag behind last year, but imports from Canada by the end of June were 3% greater than for the first half of 1953. Total imports for the first six months amounted to 991,982 tons, 102,678 tons less than for the same period in 1953. Imports from overseas were down 130,785 for this period, while imports from Canada increased by 27,736 tons.

Exports of wood pulp have increased appreciably this year, and for the first six months were 140,000 tons, an increase of 77,000 tons over exports for the first half of 1953.

Inventories of wood pulp at the end of June of 673,000 tons were at their highest level since August of last year when they totaled 683,000 tons. June end inventories this year consisted of 183,000 tons at pulp mills and 490,000 tons at paper and board mills.

Newsprint

Production and shipments of newsprint in North America during August, 1954, amounted to 602,637 tons and to 617,347 tons, respectively, compared with corresponding totals of 575,331 and 590,801 tons in the same month of 1953. North American production in August, 1954 exceeded that in any previous August. Output in the United States was 99,492 tons and shipments were 98,503 tons while Canadian (including Newfoundland) production amounted to 503,145 tons—the peak August record to date—and shipments totaled 518,844 tons.

Through the end of August this year United States mills turned out 42,622 tons or 5.9% more newsprint than in the first eight months of 1953 while output in Canada also was 148,238 tons or 3.9% greater than in the corresponding period of last year, thus the total continental increase amounted to 190,860 tons or 4.2%.

World demand for newsprint is expected to rise to more than 15,500,000 metric tons in the next decade, compared with the 1951 figure of 9,456,000 tons, a report issued by the United Nations Educational, Scientific, and Cultural Organization indicates.

The report—"Paper for Printing and Writing: Tentative Forecasts of Demands in 1955, 1960, and 1965"—was prepared by the Intelligence Unit of *The Economist* in London at the request of UNESCO. It is issued as No. 12 in the agency's series of papers on mass communication and is a sequel to two previous reports entitled "Newsprint Trends 1928–1951" and "Paper for Printing (Other than Newsprint) and Writing, 1929–1951 Trends."

The report estimates the 1965 newsprint requirements for Canada and the United States at 7,760,000 tons; Latin America (including all other countries in North and South America), 897,000 tons; Europe 3,914,000 tons: USSR, 1,000,000 tons: Oceania, 382,000 tons: Africa, 179,000 tons; and Asia, 1,408,000 tons.

An increase in production of nearly 6,300,000 metric tons would, therefore, be necessary, between the 1950–51 average and 1965, to satisfy the expected increase in demand during that period. Expected world demand for newsprint in 1955 is estimated at 2,120,000 metric tons over the 1951 level, the corresponding figure for 1960 being put at 4,030,000 tons.

Wastepaper

Less of the mixed grades of wastepaper has been consumed so far this year by the eastern mills than last. Although consumption of the total grades of wastepaper in the first 36 weeks of 1954 dropped 4.4% from the corresponding period last year, the consumption of mixed grades fell off 9.1%. In the same period, consumption of old corrugated increased almost 1% this year. The lower demand for mixed grades is attributed to the fact that paperboard consumers have been insisting on better quality.

The U. S. Dept. of Commerce has suggested that an inquiry be made into the technical and economic problems of utilizing waste newspapers in the production of newsprint.

A new symbol for the identification of multiwall sacks consisting entirely of plain untreated kraft has been suggested by the Paper Shipping Sack Association. The symbol consists of a red octagonal figure containing the letters ANK.

Finland

The forest products industry is continuing to enjoy a market situation in which prices are remaining firm and, in some instances, show signs of slight increases.

Demand for both paper and pulp has been lively despite the fact that Canadian and United States shipments to the European market are causing some slight readjustments in

traditional sales patterns. Finnish exports of chemical pulp during 1954 are expected to total about 900,000 tons.

With both demand and prices remaining firm, Finnish chemical pulp producers consider it very likely that total production this year will exceed the 1,385,000 metric tons produced in 1951—the biggest postwar year.

Groundwood pulp production is expected to drop somewhat in view of the probable curtailment of the use of electric power necessitated by low water levels. In northern and western Finland summer rains have improved the situation but the situation in eastern Finland continues to create concern for the power supply in the Fall and early Winter.

The effort of Finland's forest industry to increase its output of processed products is being demonstrated by the growth in paper production. It is expected that total production of all paper grades in 1954 will exceed 800,000 metric tons for the first time in history. Next year, unless a drastic change occurs in demand, production is expected to reach 900,000 tons, this jump resulting from Enso-Gutzeit's new newsprint mill at Summa, with an annual capacity of 80,000 tons, which will be in full production in 1955.

Although newsprint accounts for the lion's share of the steady increase in production, the output of other grades, such as kraft and technical papers, has also risen substantially during the postwar years.

France

French requirements continue to be far in excess of domestic production capabilities. Although long-range plans call for a gradual reduction of dependency on imports through extensive forest conservation and increased utilization of hardwood and other fibers in pulp production, it appears likely that constantly expanding consumer demand will obligate France to a long range import policy allowing foreign purchases of approximately 40% of wood requirements.

The general supply uncertainty continually prompts the French trade to call attention to the vast forest resources of the Soviet Union which are not available at present to Western European consumer nations. The French trade frequently pleads for resumption of trade with prewar suppliers in Eastern Europe, on a competitive basis.

Wood Pulp Consumption. Consumption of pulp in paper mills reached 966,847 tons during the year, still 83,914 tons below the 1951 record. Pulp imports were increased but were not of a magnitude to permit stock replenishment. Low wood imports further contributed to stock declines from 113,496 tons on Dec. 31, 1952, to 107,880 tons on Dec. 31, 1953. Pulp and wood imports have been relatively low because imports from OEEC member countries have been curtailed, due to European Payment Union considerations. Favorably priced wood and pulp from Sweden could not therefore be drawn upon. Finland, a nonmember country, cannot supply all the requirements and prices of Finnish wood and pulp are higher than OEEC countries prices.

Wood Pulp Outlook. With paper production running at a high level, 1951 pulp production levels will undoubtedly be surpassed. Increased consumption, however, will be dependent on increased imports. Domestic factories are running at 95% of capacity with significant expansion unlikely in the near future. As pulp is not as yet on France's liberalized import list, and as Finland cannot be expected to deliver all requirements for the reasons mentioned above, pulp consumers are drawing on stocks and hoping that when France liberalizes further, probably in the Autumn, pulp and wood will be included on the lists. The consensus of trade and government officials is for liberalization in this sector which will raise the level of imports considerably. France is at present dependent on imports for 50 to 60% of requirements. Whether or not liberalization will have any salutory effects on consumer prices will, of course, be dependent upon revisions in the perequation price system which at the present time permits the survival of marginal French producers.

Paper Production Outlook. France is not a traditional importer of paper, imports of raw materials for conversion being preferred. As France is following a protectionist policy in respect to the paper industry, imports will continue to be limited to urgently needed categories caused by discrepancies between domestic production and demand. As domestic paper production is increasing and should be able to satisfy all normal domestic requirements, exceptional demand, such as the upswing in activity precipitated by the Korean war, will be the determining factor in future paper imports.

Norway

The major problem confronting the Norwegian wood pulp industry continues to be the critical shortage of pulpwood from domestic sources. Official preliminary results of the 1953/1954 timber cutting season, which ended in June, indicate a total cut of 6,959,890 cubic meters. This is a shade below the preliminary 1952/1953 figure of 7,032,330 cubic meters; about half this timber in 1953 went into the production of pulp, but that quantity was insufficient to supply all the raw material required by Norwegian pulp mills even during a period of comparatively slack production. Earlier this year the industry estimated that it would have to import about 1 million cubic meters of pulpwood if a high level of production were to be maintained throughout 1954. With pulpwood imports of 20,108 cubic meters in May and June, Norway's total imports of this commodity amounted to 146,848 tons in the first half of this year; about 103,000 cubic meters were purchased from Sweden and the rest from Finland.

As the shortage of pulpwood is largely of the spruce variety, some Norwegian pulp producers are exploring or experimenting with the use of other species for cellulose production.

At the same time, other pulp producers are increasing their utilization of small-dimensioned timber and logging waste. One interesting result of this development is its apparent adverse effect on the domestic fuelwood market.

Wood Pulp Market. Spokesmen for both the mechanical and chemical pulp industries characterize the market situation as good, and both declared in August that the entire projected 1954 output of their respective industries had been sold.

From the frequency with which the subject has been raised in the local press and trade journals, it must be concluded that the Norwegian producers are seriously concerned about the long-range implications of increasing sales of pulp by North American producers in the European market. The Norwegians, however, have publicly taken the position that such sales do not represent a threat to the local industry as they only serve to supplement the market by covering the demand which the Scandinavians are unable to supply because of limited production capabilities.

Portugal

The Companhia Portuguesa de Celulose, whose pulp and paper plant located at Cacia, near Aveiro, was built with F.O.A. financial aid, continues to increase its pulp production both for home and export markets. During the first 6 months of the year it produced and sold a total of some 13,000 tons of kraft pulp. Of this figure, 4000 tons, with a value of 13,000 Contos ($454,500) was for the domestic market and 9000 tons with a value of 27,000 Contos ($944,000) was for export. Of the latter figure the greater part went to England but important shipments were made to Germany and the Netherlands. A contract to ship to Germany on a regular basis was recently signed. A contract with British paper interests has been negotiated and will be signed in the next few weeks which provides for the shipment to England of 10,000 tons of kraft pulp per year for the next 5 years. A trial shipment of 50 tons of kraft paper to Norway was recently made and it is hoped that this will develop into further business.

Southern Rhodesia

Concomitant with the presentation of the Federal budget for the year July, 1954 to June 30, 1955, the Minister of Commerce and Industry had made public the federal currency allocation schedule for the period July 1 through Dec. 31, 1954.

Many items previously under quota have been added to the unrestricted list. Items on the unrestricted list are defined as those the import of which is not subject to currency quotas. They still require import licenses, but these will be issued, subject to scrutiny only. Pulp and paper items are as follows: unmanufactured timber; wallboard and hardboard (excluding plasticized surfaced board); paper for converters as defined; printing paper; books, printed music, newspaper, periodicals, and paper dress patterns; newsprint and newspaper matrix advertisement services requirements; printers' requisites special; sensitized paper.

Sweden

An important step in improving the conservation and harvesting of Sweden's forests is being undertaken this year on an experimental scale, in the form of exchanging land holdings to enlarge individual land lots.

The purchase and sale of property is strictly restricted to government control through court order and in practice is extremely difficult to achieve since the individual farmer's rights are always overwhelmingly protected by law. The principal difference between land "exchange" and "interchange" appears to be that the former requires the approval of both parties while the latter—since the 1951 amendment to the Land Parcelling Act— can and is freely exercised at the instigation of the Government Forest Service against the will of one of the parties. This appropriation of property is widely accepted as ethical in Scandinavia although it may be fundamentally repugnant to the Common Law principle of private property sanctified in Anglo-Saxon tradition. A forest landowner in Sweden is bound to protect his endowment and failure to promote its upkeep can lead to forced sale for whatever the government deems as fair compensation. This is a thesis which some independent forest owners and pulp producers have strenuously opposed.

The final results of the official second national forest census of Sweden are expected to be published toward the end of 1954. Based on preliminary conclusions of the Forestry Research Institute in Stockholm it has been officially estimated that tree felling henceforth will have to be limited in Norrland to 70% of the annual cut of the immediate prewar period.

A new awareness of the danger of further forest depletion has already resulted in such concerted conservation measures that several private sources consider the critical conclusions to be drawn from the second forest census have already been ameliorated even before the census results have become final.

The only Swedish paper mill, Holmens Bruk, which continued large-scale exports of newsprint to the United States after the war, has decided to cease such exports. The resulting loss of dollar revenue for Sweden will be about SKr 7.5 million ($1.45 million) per year, and Swedish shipping to the United States also will be affected. The reasons for the decision are the steadily decreasing profitability of exports to the United States and the increasing Swedish paper consumption, which necessitates cutting down the least remunerative exports.

Argentina

The Argentine government considers it "a matter of national interest" that in due course Argentina should become independent of paper imports. One step on this road is the expansion of pulp production. Output of mechanical pulp in Argentina has risen from 6340 tons in 1951 to 32,000 tons in 1953, while the respective figures for chemical pulp are 33,000 and 81,000 tons. In 1954 chemical pulp production is expected to total 90,000 tons. The government's targets for 1957 are 50,000 tons mechanical and 130,000 tons of chemical pulp.

A newsprint mill using sugar cane waste is expected to be in operation within two years at Tucuman, 75 miles from Buenos Aires. A New York concern is said to be financing the operation.

Switzerland

A Swiss firm has developed and offers a new paper surfacing process which is inexpensive, does full-sizing, waterproofing, is not subject to swelling, and gives a pliable surface, with a good glaze and brilliance.

United Kingdom

The main problem confronting the United Kingdom paper industry now is whether future supplies of papermaking raw materials will be sufficient to cope with the demand for the finished products. In addition to meeting the demand for paper, the United Kingdom paper manufacturers are now looking ahead to the coming Winter months when conditions will prevent shipments of wood pulp from Scandinavian ports and are therefore anxious to build up their wood pulp stocks now. The general opinion in the United Kingdom paper trade seems to be that control of pulp and paper imports should and could be ended at the present time or, failing this, that the government should at least allocate additional currency for the purchase of imported wood pulp to assist the industry in improving its stock position.

The United Kingdom paper industry realizes, however, that it is unlikely that the control of wood pulp imports will be abolished while supplies of newsprint are still subject to restriction. In this connection the Ministry of Materials announced recently that there is little hope of ending newsprint rationing in the United Kingdom until sometime during 1955 and only then if the balance of payments situation permits.

Yugoslavia

The plan is composed along the same lines as last year's, although the introductory section dealing with the economic developments of the previous year is omitted. Further increases in production are predicted, more emphasis is laid on the production of consumer's goods and the development of agriculture, and some changes in the economic instruments, including the foreign exchange system, of the country provided. Chief among these are the introduction of a progressive system of taxation of enterprise profits and the decentralization of wage controls to the district level. For the rest, the prescription is "the mixture as before," with somewhat less emphasis on the better use of existing capacities, which was given a prominent play in last year's document and is repeated, and somewhat more emphasis on the completion of key projects.

Prices of certain key raw materials and final products will be fixed and domestic supplies secured by rationing. The physical volume of production is to rise by 15.1% over the estimated results for 1954.

New Zealand

"Jigsaw" is one way to describe the $35 million newsprint project Merritt-Chapman & Scott, in association with two other contractors, is constructing 200 miles south of Auckland, N. Z., for the Tasman Pulp & Paper Co. As items of machinery ordered from around the world arrive at the site in quickening tempo and more buildings go up, the big picture is coming to life. By late next year, it is expected to be complete and the "Down Under" country will have its first newsprint industry.

The project is one effectively illustrating that modern-day trends have largely outmoded the old concept of "four wall" construction, where you first erected the building itself and then installed the equipment. Today, in the age of the "Chemical Century," a mill such as the one at Kawerau, N. Z., is in good part designed and built around the equipment, with construction of the building and installation of equipment moving ahead simultaneously. Result: as construction proceeds, all equipment scheduled to be "built in" must be on the scene, ready for immediate placement.

Construction by this "jigsaw" method calls for special planning and ingenuity where purchase orders for equipment are placed in four different continents on a timetable requiring synchronized delivery at a project site thousands of miles away.

Characteristic of this "built-in" type of modern-day engineering and construction is the manner in which the largest single piece of equipment for the mill at Kawerau—the paper-making machine itself—is being installed. Manufactured in England, the machine will be 200 ft. long and weigh 2000 tons when fully assembled.

It is being fabricated and shipped piecemeal to New Zealand in sections up to 60 tons for installation as the work progresses. Schedules are being arranged so that the final section of the machine will be on hand for installation as the project nears completion.

Bagasse

Here is a raw material annually available in tropical and subtropical countries around the world in tremendous tonnages, from which a long list of vital products have already been made, with many more seemingly possible with further work. Yet very few known uses are now being commercially exploited.

Bagasse today is being used to produce animal and chicken litters, filler material for dynamite, plant mulches, paper and paper pulps—oil well drilling mud additives—building and insulating board—cattle feed, thermosetting and thermoplastic resins, and a Caribbean plant has been announced to use it as a furfural manufacture. This list is not represented as being complete.

Chemically, bagasse can be used to produce many other important products. The brief and probably incomplete product list just given certainly demonstrates wide versatility of use. This, with its annual availability, are bases for the great world interest in this agricultural raw material over the years.

Some of this audience may not be familiar with the appearance and characteristics of bagasse; therefore, at the risk of boring those who are, please let me review some facts about it.

Bagasse is the pith containing fibrous residue resulting from the grinding of sugar cane to extract the juices from which sugar, molasses, and sometimes syrup are ultimately made. As produced from the last mill in the sugar house, bagasse is a yellowish gray-green fibrous mass with fiber bundles sometimes as much as 6 in. long and, of course, other bundles and pith fractions varying on down to very small size. As it comes off the last mill, bagasse will average close to 50% moisture. The fiber and pith fraction will average from 45 to 48% with $2^1/_2$ to 5% soluble solids. These analyses necessarily vary, first because final moisture varies with sugar mill efficiencies—but even more importantly because of the rather wide variances in today's sugar cane varieties.

Different cane varieties, of course, vary in the per cent of pith versus long fiber. Newer cane varieties in Louisiana are small diameter hard canes, while most older varieties are much larger and softer with consequent differing pith to long fiber ratios. As an average, most investigators consider the ratio of pitch to long fiber to be about equal and this may be a fair assumption. The long fiber in bagasse ranges from 1.0 to 5 mm. in length, its diameter varies from 0.016 to 0.05 mm., giving a length to diameter ratio actually greater than many wood fibers. In comparison to wood fibers, bagasse would be classed as an intermediate in length. The pith fraction forms the walls of the cells in which the cane juices are held, is very thin, while at the same time binds the fibers together.

Chemically, bagasse pith and fiber are the same within the limits of analytical accuracy. Cellulose, ±53% is the principal constituent of bagasse fiber, but it also contains lignin, 2.5%, pentosans, ±23%, sucrose, glucose, fats, waxes, gums, acids, silica, and ash. McElhinney has found means to use bagasse as a source of furfural, furfuraldehyde, formaldehyde, and various ketones in his research.

Bagasse being a residue from sugar cane processing is produced in tropical and semitropical areas of the world. Lathrop has estimated normal world production to be 20,000,000 tons per year. Florida and Louisiana are the producing areas in this country, with Louisiana producing about 750,000 tons per year. With this quantity of fiber production from sugar cane, it may be readily seen that bagasse offers a very important additional source of cellulose fiber, particularly in view of the fact that Forestry Service reports that even now in the fast growing woodland areas of the South, the annual drain through the cutting of wood equals or exceeds the rate of growth, and certainly will exceed it as new plants being built commence to consume wood fiber.

Cane must be ground shortly after being harvested and in some areas the harvesting season is short—about 75 to 90 days in Louisiana, while grinding capacity of individual mills is rather large. Perhaps the average Louisiana mill will grind close to 100 tons of cane per hour, though many mills are much larger, particularly in Hawaii, Cuba, and some Caribbean Islands. Since moisture-free bagasse will average close to 15% of the weight of cane ground, substantial tonnages of bagasse are annually produced at each mill. This, of course, is a distinct advantage to the user of bagasse—his material is harvested—brought to a central location and processed there in substantial quantities to produce other products. For this reason, gathering costs and problems of raw fiber procurement are minimized. This perhaps is another reason why bagasse has intrigued many users and processors of fibers for so long a time. Certainly this fact gives bagasse an advantage over straw, corn stover, and wood today.

In Louisiana, cane is harvested annually with yields averaging close to 24 tons of cane per acre or 3.6 tons dry bagasse per acre. Converting this to cellulose per acre per year and comparing the growth data on cellulose grown per acre per year in the form of wood makes sugar cane rank very high as an annual source of cellulose. Many tropical and subtropical areas which are large producers of sugar, such as Cuba, Hawaii, and the Philippines, obtain cane yields several times the Louisiana average and their production of cellulose per acre per year from cane reaches rather remarkable figures.

Sugar growers, scientists, and research workers have long been intrigued by the possibility of using bagasse as a source of industrial materials. Litkenhaus, in his study, reports one process for pulping bagasse which dates back to 1838. Being a lignocellulosic fibrous material, bagasse has attracted much attention as a fiber for paper pulps of many types, as well as a basic material for resins and some chemicals. Some of the lesser known uses of bagasse are very interesting. Sugar cane wax is now being produced and refined at Gramercy, La., in grades equal to Carnauba. This comes from cane and a part of the original wax is carried over in the resultant bagasse.

Bagasse is being processed and sold as a litter material for chickens and cattle. Bagasse pith has been used for a long time as a filler material in the manufacture of dynamite. Several Louisiana mills and Louisiana State University have combined bagasse with molasses and in some cases other

materials for cattle feeds, and at least two sugar producers are now marketing bagasse cattle feeds. Bagasse is also being marketed in increasing volume after processing, as a lost circulation material of importance in the drilling of oil and gas wells in certain strata. Composted bagasse has many of the characteristics of peat moss and in many respects is superior to this widely used mulch material. This can be another important use of this material.

Furfural often has been successfully produced from bagasse and in November, 1953, a large sugar mill in Puerto Rico announced a project in which the Quaker Oats Co. is cooperating to construct a large plant to produce this important chemical from bagasse. Here is chemurgy really at work.

Furfural and the furans are exceedingly important, with excellent prospects that their importance will increase as industrial, chemical, and pharmaceutical materials. Bagasse, as a raw source of these materials, may become very important as furfural usage and furan chemistry advance.

The Valite Corp. has made use of bagasse after processing as a filler material in very interesting molding compounds. T. R. McElhinney, vice-president and technical director, holds a number of patents on bagasse processes with others pending. He has, for example, produced some remarkable thermosetting and thermoplastic resins based on bagasse, which have found use in the manufacture of phonograph records, molding compounds and excellent laminates with paper, cloth, and glass fabrics. One laminated product is a gear stock of outstanding qualities of strength, wear, and shock resistance as shown in actual usage.

Much interesting and valuable work on bagasse as a raw material base for varous types of plastics has been done by many researchers. Great credit for original research in this field is due the U. S. Dept. of Agriculture and its staff of scientists. Particular tribute should be paid to the memory of the late D. F. J. Lynch for his outstanding work on bagasse while head of the U.S.D.A. Agricultural Research Laboratory at Ames, Iowa, and later while Director of the Southern Regional Research Laboratory at New Orleans.

Bagasse, of course, has great industrial importance as a fuel in sugar mills and in some tropical areas as a fuel for steam locomotives. It is not an ideal fuel, in fact, as such, it has many disadvantages. However, Arthur Keller of L.S.U. has estimated that 95% of the world's bagasse production is used as fuel in the sugar factories which produce it. In many foreign factories, bagasse production is so high that boilers are operated inefficiently by design to consume the bagasse produced. In Louisiana, one ton of bagasse is generally regarded as being equal to 12 MCF of 1000 B.t.u. natural gas or 2 barrels of fuel oil.

One outstanding product from bagasse is Celotex board in its various forms. This great industry established in Louisiana in 1920, was the first in that area to successfully produce commercial building-board products from bagasse. Building board is now made of bagasse at several points over the world, one very successful operation being the Flintkote Co.'s plant at Hilo, Hawaii. Bagasse board has a good future, as processes have now been found to produce excellent hardboards with good strength characteristics that exceed similar boards from other raw materials being marketed today.

The history of bagasse paper projects is a long one, dating back well over 100 years. Many processes have been developed—mills have been built almost wherever sugar cane has been grown—most have failed, principally for economic reasons, although W. R. Grace Co. produces paper from bagasse in Peru. Mills exist in Formosa; the Cellulose Development Co. of England, using the Pomillio process has built several plants, some in this hemisphere and one in the Philippines. Bagasse paper is used in places for plant mulch paper; and Container Corp. uses bagasse in Columbia in the manufacture of 0.9 corrugating board. Good grades of bond, writing, bank note, and other types of paper are now being made on which tests have shown the physical characteristics to be equal to or better than similar papers produced from other sources.

Early in 1953, Valentine Pulp & Paper Co., Inc., was organized for the purpose of producing bleached papers and pulps from bagasse at a mill now nearing completion near Lockport, La. This mill will utilize processes developed by T. R. McElhinney, vice-president and technical director of Valite Corp. of New Orleans, and other processes developed independently by E. L. Powell, cellulose consultant of Chattanooga, Tenn. Papers made by processes to be used in the Valentine mill have been made on laboratory—pilot plant—and finally commercial paper mill equipment leased for the purpose. They have been tested on commercial scales in various printing plants and by paper converters with excellent results, and the actual operation of Valentine's mill will give bagasse a real commercial-scale proving ground in the highly competitive markets of this country. The processes to be followed make use of whole bagasse rather than the separated long fiber as has so often been advocated. Special pulping and paper mill equipment is not required in this mill.

Much more could be said about bagasse and its potential uses. Mention could be made of its potentials as a source of nitrating and dissolving pulps—both of which have been successfully produced. Much could also be said of the possibilities that the waste liquors from Valentine's new mill may hold—of the baling and storing of bagasse and many other points. It is a fascinating raw material holding great possibilities for the persistent researcher. Its secrets are certainly not yet fully known and its commercial and industrial uses are largely yet to be exploited.

In years to come, bagasse should be an exceedingly important source of many vital materials.

—by W. J. Amoss in *Chemurgic Digest*, June, 1954.

Handling and Storing of Paper

"Profit" is a term used to describe what all lithographers are working for and to describe what they expect from each job when it is in the estimating and scheduling stages. "Paper Waste" or "Wasted Paper" are terms that can be used in many lithographic shops to describe what happened to that "Profit."

Today the reduction or elimination of unnecessary waste is of prime importance to all shops large or small. Too often, however, very little thought is given to the problem until the actual losses have been suffered and it is too late to make any correction.

The first step toward reducing waste should be taken when the paper is ordered. Tell the merchant, or the mill, what you want and make sure that you both thoroughly understand each other, preferably in writing. The size of the sheet and grain direction are of first importance. The size, because ordering a sheet larger than is needed will mean that you start with extra waste. Ordering the grain the wrong way or receiving it the wrong way from the mill because it hasn't been specified can mean extra losses in press or bindery operations. Most paper, of course, is ordered "grain long" and for good press operation this is usually the best. However, subsequent operations such as folding or the end use, as some labels, may require that the printer run "grain short."

Basis weight, of course, will be specified and generally causes little trouble, although if a mailing piece is being planned the matter of postage should not be overlooked.

Caliper is a specification that is usually governed by the basis weight and finish and most of the time is not of great importance to the printer. If the job to be done is a calendar pad, a book or similar job, caliper can be the cause of an endless series of headaches.

Color is another specification that should be understood. "White" alone is not enough as there are many shades of white. This can probably best be handled by an exchange of samples between the printer and the salesman.

In considering the matter of paper specifications the printer should not neglect the wishes and desires of *his* customer. The whole job can be wasted—paper, ink and press time—if a customer suddenly decides that the stock isn't suitable or will not do the job he expected.

Another very important specification is moisture content of the paper. Some lithographic plants are completely air conditioned, very many have humidifying equipment that enables them to maintain a fairly constant humidity in the pressroom during the colder months of the year. If either of these conditions exist the printer should specify on his order the humidity at which the paper will be run. The mill will then be able to make the paper with a moisture content suitable for the specified humidity. More about this later.

After the paper specifications have been decided on, the printer should give some thought to the packing, loading, and handling of the paper.

Carton packs give the utmost protection from the mill to the press and frequently the printer can reuse the cartons to protect finished work or even work in process. Most printers, however, will order paper shipped on skids and this is where considerable paper can be wasted or saved depending on the amount of thought given when ordering. If the press feed equipment permits putting the entire skid into the press as it has come into the plant, this should be done. In this event it will be necessary to make sure that the paper is not shipped on skids that are much larger than the sheet. Generally, the skid platform can have a slight margin all around and still feed satisfactorily. A slight margin is necessary to give the edges of the paper the utmost protection. The runners should be placed to run across the press—usually the grain direction. They should be high enough so that power handling equipment can be used but no higher. If skid runners are too high they may collapse in transit if subjected to severe shock. Where the size of the sheet permits, the runners should be set in 3 to 5 in. from the long edge of the skid. This is particularly important if space limitations make double tiering of skids in storage necessary. Double tiering can be done but should be avoided as much as possible to prevent damage and accidents. The runners should not be set in so far, however, that the fork or platform of the lift truck used by the printer will not go between the runners. Proper consideration of these skid details will possibly save handling the paper unnecessarily, thus saving labor and the sheets that are always damaged in such handling. The materials used and construction of the skids can be left to the mills concerned. They have learned from experience the best way to build a skid to protect the paper as much as possible.

While in the pressroom or storage there are a number of things that can be done to reduce waste. Perhaps the most important single thing would be to educate the paper handlers and pressmen about the value of the commodity. By the time it gets to the press the value has been increased. It is no longer just the cost of the paper. It is the cost plus freight, trucking, handling, storage, overhead, etc. The great majority of pressmen and paper handlers will do their utmost to save as much as possible of the paper they handle especially if it is pointed out to them that they are the only ones that can save it at their particular part of the operation. I have found that when they realize that it is a valuable property they are handling and not "just a sheet of paper," efforts are increased to save as much as possible.

The next thing to do is to order paper sufficiently in advance so that the mills can give the order proper attention and more important—that the paper can be left in the pressroom or printer's storage long enough to bring it into balance with the pressroom atmospheric conditions. This may be a week or more depending on conditions and seasons.

A "sword" hygrometer such as introduced by the Lithographic Technical Foundation is very useful in determining the suitability of a specific lot of paper for specific pressroom conditions. Generally I have found that printers can handle paper that is on the moist side with greater ease than they can handle paper on the dry side.

It is important to remember that paper is a natural fiber that is frequently treated in an unnatural way. The end result can be a terrific headache and plenty of waste. From actual tests it is known that some "free" sheets over 60 in. long can stretch or shrink a half inch or more in the "grain" direction when exposed to humidity variations of 50% R.H. That is, if the humidity changes from 20 to 70% R.H. or vice versa the sheet will stretch or shrink about $^1/_2$ in.

Because of this natural tendency of paper to change in size, it is important for all shops, and particularly those not air conditioned or humidified, to handle their paper carefully. When received in the plant it should be held long enough to come to room temperature. The paper handlers and pressmen, as a matter of habit, should not open more than is needed at the moment. In other words, keep it in the mill wrapping or cartons as long as possible. If it is to have more than one printing it should have some protection in the pressroom between printings. There are plastic covers that can be purchased and used for this purpose, also rubberized cloth covers. If care is used when the skid is first opened, the mill wrapper can be cut at the bottom only and then raised up off the skid and saved to protect the work after it is printed. If this is not feasible, one corner can be slit to remove the wrapper and later fastened with tape.

The important thing is to protect the paper from being affected by the changes in atmospheric conditions in the plant during the time it is being processed. This may mean a little extra work but it will pay off by preventing wrinkled sheet, out-of-register sheets, and the resultant waste.

If it is necessary to run paper that is out-of-balance with pressroom conditions it may be necessary for the printer to hang it for 24 hr. or so in order to condition it. This will usually do the job and make it possible to get started quickly. Careful handling of paper is particularly important if it has been exposed to low temperatures for any length of time as in transit from mill to the pressroom. Opening the skid or carton too soon after arrival in the pressroom will result in wavy edged paper. This is caused by the moisture in the warm pressroom air condensing on the edges of the cold paper.

Many of the items listed above may seem unimportant or of minor importance but during past years many cases of trouble, excess waste, and lost press time could have been prevented if proper thought had been given to them when the order was first placed.

—by W. Keith Gainer in *Share Your Knowledge Review*, July, 1954.

Paper Products Survey

Variety stores are by far the most popular outlets for purchases of paper products, according to a survey by the Research Dept. of Curtis Publishing Co. Variety stores are patronized by 60% of paper product users, with food stores second in order of popularity, department stores third, and hardware and house furnishings stores fourth.

The survey was conducted by mail in May, 1954, and covered 1000 *Ladies' Home Journal* subscribers. Names of subscribers were selected to parallel geographically approximately 3,000,000 subscriber names. Replies were received from 648 respondents, a 64.8% return.

Highlights of the survey showed that 86% of the respondents currently use shelf paper. Of those who use shelf paper, 89% use it to cover shelves, 82% use it to line drawers, and 34% use it to wrap packages. Of those who use shelf paper to cover shelves, 19% use the kind with the decorative edge that folds down over the edge of the shelf, 35% use the plain kind that has no decorative edge but merely covers the shelf, and 45% use both types.

Among total users of shelf paper, 25% buy it once a year, 47% buy it twice a year, 17% but it three times a year, and 9% buy it four times a year. The variety store is patronized

by 61% of total shelf paper users. Food stores were mentioned by 23%, department stores by 14%, hardware stores by 5%, and house furnishings stores by 3%. It appears there has been an increase in the amount of shelf paper currently used compared to the amount used a year ago. Among total users, 13% say they use more today, 7% say they use less, and 75% say they use about the same as they did last year.

Seven out of ten respondents use paper doilies. Among users of paper doilies, 42% buy them once a year, 30% buy them twice a year, 10% three times a year, and 17% four times a year.

Again the variety store is the most popular outlet, mentioned by 72% of paper doily users as the place they last bought this item . . . 16% said food stores . . . department stores, 11% . . . hardware and house furnishings stores, 2% each. It appears that paper doilies are being used today to a somewhat greater extent than a year ago in that 14% say they currently use more, 10% use less, and 70% use about the same amount they did a year ago.

One out of three respondents uses paper place mats. Among users of paper place mats, 38% buy them once a year, 24% buy them twice a year, 10% buy them three times a year, and 21% buy them four times a year.

Among various paperware items, napkins, plates, and cups are much more widely used by respondents than are paper table covers, forks and spoons, or party packs:

Paperware items	*% who bought in last year*
Napkins	95
Plates	84
Cups	77
Table covers	33
Forks and spoons	28
Party packs	22

Butchers' Paper

Butchers' papers are wrapping papers of various construction, types, grades, and finishes, all of which, however, have certain characteristics in common. They are all designed to give resistance to blood and moisture penetration, to be chemically pure and sanitary, and to have sufficient strength to prevent easy breakthrough by bones.

To achieve these qualities, butchers' papers are usually sized with ingredients such as starch, alum, rosin, or a wax emulsion. They also may be wax-treated with paraffin or paraffin base oil, to increase their resistance to grease penetration.

The base stock used for butchers' papers may be sulphite pulp or sulphate pulp, or combinations of sulphite and sulphate, or sulphite and groundwood pulps. These pulps and combinations may be bleached, semibleached, or unbleached.

Butchers' papers may be dry finished, which gives them a relatively rough and unglazed surface, or water or steam finished, which gives them a smooth, glossy surface and greater density.

Butcher's papers are available in manila, white, pink, peach, or unbleached kraft (natural) color.

The more widely used types of butchers' papers are:

1. *Butchers' Manila.* Made usually from sulphite pulp or a combination of sulphite and groundwood pulps; sometimes it is made from unbleached or semibleached sulphate pulp. Butchers' manila is usually well sized to provide resistance to grease and blood penetration, and it may be steam or water finished. It is uniformly manila colored.

2. *Dry-Finish Butchers'.* Made usually from sulphite pulp, a mixture of sulphite and groundwood pulps, or from unbleached or semibleached sulphate pulp. It is well sized and has a dry finish (rough unglazed surface).

3. *Kraft Butchers'.* Made entirely, or in part, from sulphate pulp and is manufactured similarly to kraft wrapping papers, with the addition of various sizing ingredients and, sometimes, dyes and special protective components suited to its particular end uses.

Kraft Butchers' may also be semibleached to a light brown or fully bleached to white or cream color. There are two standard grades of kraft Butchers':

(a) Standard Unbleached Kraft Butchers' grade contains 90% or more unbleached sulphate fiber and tests 70% or less of the basis weight Mullen test, under standard TAPPI testing procedure. It also possesses sizing, formation, etc. to make it suitable for butchers' use.

(b) No. 1 Unbleached Kraft Butchers' grade contains 100% unbleached sulphate fiber and tests more than 70% of the basis weight Mullen test under standard TAPPI testing procedure. It also possesses sizing, formation, etc. to make it suitable for butchers' use. All rolls and bundles must be designated with the guaranteed Mullen test or the words No. 1 Kraft Butchers.

4. *Steam Finish Butchers'.* Butchers' papers which have been given a smooth, glossy surface by the application of live steam prior to the calendering of the paper are known as "steam finished."

5. *Treated Butchers'.* Butchers' papers which during processing have been treated with paraffin, petrolatum, paraffin base oils or other ingredients for the purpose of increasing resistance to grease and moisture penetration are known as Treated Butchers' Paper. These papers are usually employed as inner wraps, since the treatment may tend to weaken resistance to breaking, or bursting.

6. *Meat Interleaving Papers.* Made usually from sulphite, bleached or semibleached sulphate, or a mixture of the two pulps. It is a tasteless and odorless paper used generally for separating steaks or sliced meats, or for inner wraps or liners.

It is generally used in small sheets, either white, natural, or light peach in color. Although it is also provided in rolls and large sheets, the most popular sizes are sheets 6 by 6, 9 by 12, and 10 by 14 in. The small sheets can be obtained in dispenser packages.

7. *Water Finish Butchers'.* Butchers' paper made from a mixture of sulphite and groundwood pulps or from sulphate pulps which have been given a hard, glossy surface by the application of a fine spray of water or by the moistening of the rolls before calendering are known as "water finished."

8. *Waxed Butchers'.* Made from bleached, semibleached, or unbleached sulphite or sulphate pulps and heavily waxed on one or both sides. Waxed butchers' gives a high degree of resistance to grease and moisture penetration and is generally manufactured in the 40 lb. basis weight only.

9. *Vegetable Parchment.* (See "Vegetable Parchment" category for details of manufacture and sale.)

Vegetable Parchment is sometimes used by butchers and meat packers, usually for interleaving or as an innerwrap where its purity, its degree of resistance to grease and oil penetration, and its quality of allowing the free passage of air, which permits the wrapped product to "breathe," are valuable in the packaging of fresh meats and poultry.

Vegetable Parchment can be obtained in large diameter jumbo rolls, standard 9-in. diameter rolls, and small "pony" counter rolls, 5-in. in diameter, which are sold in widths of from 6 to 12 in. Vegetable Parchment may also be obtained in many sizes of sheets, ranging from 5 by $6^1/_2$ in. (packed sometimes in dispenser boxes, 1000 sheets to a box) up to the largest size permitted by the full width of 72 in. in the jumbo roll.

Definitions and Miscellaneous Information

1. *Basis Weight.* The weight in pounds of 500 sheets, 24 by 36 in., or 864 sq. in. each. The 40-lb. weight is the most popular.

2. *Rolls.* Standard roll is the counter roll, 9 in. in diameter and 12, 15, 18, 20, 24, 30, and 36 in. in width.

3. *Sheets.* Standard size sheets are: 12 by 18, 13 by 18, 18 by 24, 18 by 26, 20 by 30, 30 by 40, and 24 by 36 in.

4. *Bundles.* Sheets are usually packed flat in bundles weighing 100 lb.

5. *Special Weights and Sizes.* Orders for special weights and sizes are usually required to fit machine trims in the same grade, basis weight, and diameter of rolls and usually require a minimum quantity of 5 tons, or more.

6. *Billing Weights.* All butchers' papers are billed at the scale gross weight, which includes wrappers, twine, and plugs.

7. *Commercial Delivery.* All shipments of butchers' papers are considered good commercial delivery when the actual basis weight does not exceed 5% above or below the specified basis weight. All shipments of butchers' papers in excess of 5 tons are considered good commercial delivery if the over delivery or under delivery does not exceed 5% of the specified tonnage. All shipments of 5 tons or less are considered good commercial delivery if the over or under delivery does not exceed 10% of the specified tonnage.

8. *Formula for Computing Weight and Yardage.* The same tables and formulas may be used for these purposes that are used for kraft wrapping papers.

—from *American Paper Merchant*, August, 1954

Sampling Wood Pulp

A folding marker gage, giving a commercial and practical application to a calculated mathematical interpretation of the procedure and rules laid down in Appendix 1 of the Rules Booklet issued by the British Paper and Board Makers' Association and the British Wood Pulp Association for the sampling and testing of consignments of pulp, has been patented.

This gage has been based upon a calculated mathematical interpretation of the aforementioned "conditions of procedure."

The measuring gage comprises a plurality of rules of different lengths corresponding to the varying heights or thickness of the bales, each being of a length relatively proportional to a particular height, in conformity with the aforesaid rules.

The top leading edge of the connected set of rules—hingedly connected together along their long sides in order that the rules may be folded to enable each scale to be used independently from the others—corresponds to the *top sheet* of the bale, the figures 2, 3, 4, 5, and 6 respectively, marked on each rule, representing the *first sheet* positions of each bale (measured from the top of the bale) in each group or series of 6 (six) bales, when the cycle is then repeated according to the bale's predetermined height.

Having located the position of the *first sheet* appropriate to the predetermined height or thickness of the bale, the full length of that rule applicable to such height is then used as a measure to determine the withdrawal points of the next four successive sheets to be taken from that bale, thereby conducting the operational procedure according to the stated prescribed rules.

It is essential that no bands or wires are cut prior to the marking off process which might in any way alter the predetermined height. In the case of wrapped bales it is only necessary to cut a wire running the length-way of a bale, for opening up the bale to facilitate the measuring and marking of the sheets to be sampled.

The hinged scales or rules forming the measuring gage are compiled in three sets, each set covering a range of seven different bale heights or thicknesses at a time, as follows: (1) 12 to 18 in. over-all bale height or thickness; (2) 19 to 25 in. over-all bale height or thickness; (3) 26 in. to 32 in. over-all bale height or thickness.

Aerial view shows 1800-acre site of Bowaters Southern Paper Corp.'s new $60,000,000 pulp and paper mill on the Hiwassee River at Calhoun, Tenn., 40 miles northeast of Chattanooga. Situated in the heart of the Tennessee Valley, the giant plant is the third and largest newsprint-from-pine mill in the South with an initial annual capacity of 130,000 tons of newsprint and 50,000 tons of kraft pulp. The main manufacturing building in the foreground houses two paper machines capable of turning out newsprint 252 in. wide at the rate of 2000 f.p.m. The plant will employ about 750 people

Patentee: W. S. Walley, M.Sc., A.R.I.C., Sindall and Bacon, 42A Buckingham Palace Road, London S.W.1.

Bowaters

Bowaters Southern Paper Corp.'s new pulp and paper mill at Calhoun, Tenn., began production of newsprint from southern pine in mid-July, 1954. This new southern plant has an initial annual capacity of 130,000 tons of newsprint and 55,000 tons of kraft pulp.

It is the third and largest newsprint mill to be built in the South, and is the first to be entirely financed by a newsprint manufacturer from its own resources. The pioneer mill at Lufkin, Tex., built in 1937, and the Coosa River newsprint mill at Coosa Pines, Ala., which began operations in 1950, were largely financed by the newspaper publishers of the South.

One of the reasons publishers were willing to help finance these two mills was to encourage members of the newsprint industry to build such plants of their own in the South, and Bowaters is the first of these developments.

In support of the new Tennessee mill, more than 100 Southern newspapers—many of which were formerly supplied from Bowater's huge newsprint mill at Corner Brook, Newfoundland—contracted to purchase its entire output of newsprint for the next 15 years, thus assuring capacity operation.

Bowaters Southern Paper Corp. is wholly owned by The Bowater Paper Corp. Ltd. of London, England, one of the world's leading producers of newsprint and also a large manufacturer of other kinds of paper in England. In addition to its paper and pulp mills in Newfoundland, the organization operates pulp mills in Norway and Sweden. The kraft pulp produced in the new Tennessee mill will be shipped to the organization's mills in England.

Sir Eric V. Bowater, chairman, The Bowater Paper Corp., Ltd.

It is significant that this world-wide organization should turn to the southern United States for its present program of expansion in the manufacture of newsprint and pulp. The major factor in choosing the southern site for the mill was the availability of wood from the vast pine forests of this region. A fast-growing species of wood, southern pine trees mature to pulpwood size in 25 to 30 years compared to the 70 to 80 years needed for the growth of northern trees traditionally used in the manufacture of newsprint. Because of their fast-growth cycle, pine trees in the south can be managed in a manner similar to any crop.

Plans for the mill were first formulated in the early postwar years. The 1800-acre plant site on the banks of the Hiwassee River at Calhoun, midway between the cities of Cleveland and Athens, Tenn., was chosen after an extensive search that spread throughout the greater part of the North American continent. More than 150 firms from all over the United States were engaged in the two-year construction job.

The plant is favorably located in regards to rail, highway, and inland water transportation, an important element in selecting a paper mill site. It is bounded on one side by U. S. Route 11 and the Southern Railway System and on another by the Hiwassee which is navigable for barge traffic. All three methods of transportation are used to bring to the mill its daily supply of some 900 cords of pulpwood: by truck from nearby areas, by rail from more distant points, and by barge throughout the Tennessee River Valley.

One of the outstanding features at this mill is its gigantic wood storage pond, the first large-scale underwater storage installation in the world. An enormous bowl—500 ft. across the top and 380 ft. at the bottom—the pond holds approximately 30,000 cords of pulpwood, enough to keep the mill running for about 6 weeks. This method of storage is designed to eliminate wood deterioration, and will permit Bowaters to take wood at almost any time from farmers and landowners in the territory.

The company will have some 200,000 acres of forest lands in Tennessee, North Carolina, Alabama, and North Georgia. A program of planting pine seedlings on company-owned property was begun several years ago, and by the end of 1954 close to 10,000,000 of these seedlings will have been set out. Since a large part of the mill's pulpwood requirements will be purchased from private landowners, the company is encouraging farmers and wood lot owners in the area to plant seedlings. They are being assisted by expert foresters who supervise the company-owned lands.

The plant employs some 750 persons with an annual industrial payroll of about $3,500,000. In addition, approximately the same amount is being spent annually to obtain pulpwood, so that for practical purposes there will be something in the order of $7,000,000 poured into the economy of the area annually by this Bowater plant. Many of the key personnel are experienced in both the Canadian newsprint industry and the Southern kraft pulp industry. For example, Karl O. Elderkin, general manager of the mill, was manager of the Corner Brook, Newfoundland, newsprint mill prior to 1938, and since then has been general manager of the Crossett Paper Mills in Crossett, Ark. So far as possible, local labor is being trained for the various jobs in the mill.

The gigantic pond in left foreground is used to store wood under water at Bowaters Southern's new mill, in contrast to normal mill operations where wood is stored on the ground. Designed to eliminate wood decay, a vexing problem with southern pine stored outdoors, the pond is the first of its kind in the world. It is capable of holding 30,000 cords of wood, enough to keep the mill running for about 6 weeks. Furthermore, it enables the company to furnish to farmers and landowners in the surrounding territory a year-round market for their pulpwood. Aligned with the pond, which is 500 ft. across the top and 380 ft. at the bottom, are unloading facilities for rail, truck and barge, the rotary barkers and the wood house

History

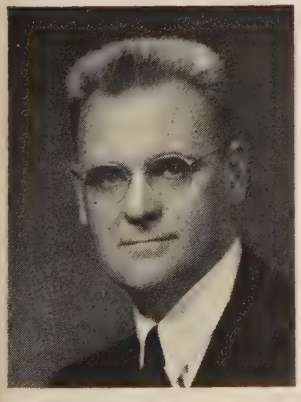
As early as 1947 the Bowaters organization started a general survey with a view to ascertaining the most suitable location for a newsprint mill in the United States. This survey indicated that there is an abundant supply of wood suited to their purpose in the southern area of the United States. In January, 1951, J. E. Sirrine Co., engineers, of Greenville, S. C. were retained to make more detailed studies of several sites in the south, which culminated in the Bowaters organization selecting a location on the Hiwassee River at Calhoun, McMinn County, Tenn., the site being served by the Southern Railway System.

This location is situated near important coal fields and has a natural gas line nearby. It also offers the facilities for obtaining a large block of power from the Tennessee Valley Authority.

The Bowaters organization filed application for a Certificate of Necessity on May 25, 1951, which was approved Feb. 19, 1952, and immediately thereafter the J. E. Sirrine Co. were authorized to proceed with the final design plans and arrange for purchase of equipment, site preparation, and construction contracts, and their supervision. The mill was completed and came into operation in June, 1954.

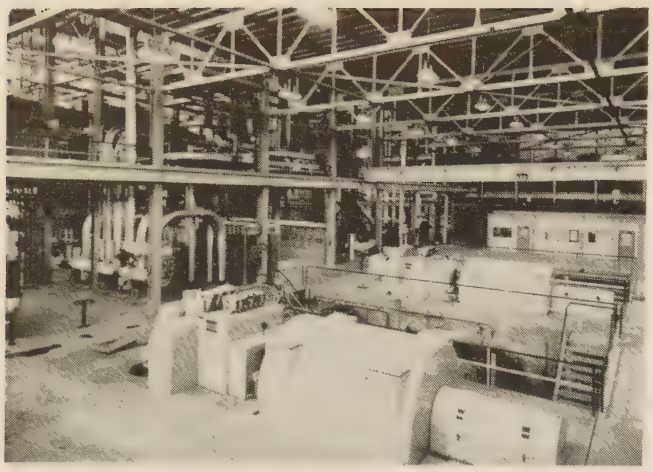
During the Spring of 1952, surveys were made for the acquisition of land, the site taking in approximately 1800 acres, much of which was obtained from the TVA; and negotiations for a power contract were entered into with the TVA for supplying approximately 17,000 kw.

Work on the general grading for the pulp and newsprint mill began on June 2, 1952, under contract with the Oman



K. O. Elderkin, vice-president and general manager

V. J. Sutton, mill manager and assistant to general manager



General view of the power house showing operating floor in the foreground. Two 10,000-kw. turbo generators, G.E. control panels shown on right are all centralized in the middle of the floor

Construction Co. of Nashville, Tenn. The first 6 months of construction from June to December, 1952 were primarily taken up with site grading which amounted to more than 1,100,000 cu. yd. of earth moving, of which approximately 260,000 cu. yd. were used in construction of the log pond. An additional 520,000 cu. yd. of earth were moved in the construction of the process waste system, including the reservoir, the primary clarifier, and the sludge disposal basin.

On Sept. 10, 1952, the pile driving operation started and these operations ended Feb. 23, 1953, during which period the Raymond Concrete Pile Co. had driven 6099 piles for the building and equipment foundations. The average length of pile was 33.29 ft. and the average sustained rate of driving with four rigs was 425 piles per week.

Foundation work by the general contractor, Fraser, Brace and Roane-Anderson was started during the month of December, 1952, and during the period of their contract there were 46,000 cu. yd. of concrete poured. It is interesting to note the sustained rate of pouring during certain periods throughout the job, as follows: March 1 through Sept. 15, 1953, 625 cu. yd. per week; Sept. 15 through Dec. 10, 1953, 1180 cu. yd. per week; Dec. 10, 1953, through Feb. 19, 1954, 570 cu. yd. per week.

A breakdown of the total concrete for the complete job, including subcontractors, gives a total of more than 65,000 cu. yd. as follows:

Raymond Concrete Pile Co.	4,904 cu. yd.
Fraser, Brace & Roane-Anderson	45,885 cu. yd.
Log Pond Bottom Slab	2,240 cu. yd.
Stebbins Engineering & Mfg. Co.	678 cu. yd.
W. L. Hailey and Co. (Filtration Plant)	8,777 cu. yd.
Oman Construction Co.	469 cu. yd.
Brice Building Co. (Facilities Building)	525 cu. yd.
Gunite Corp. (Log Pond)	1,821 cu. yd.
Total	65,299 cu. yd.

The major portion of the concrete used on the job was supplied by Cooney Brothers, who were given the contract to furnish concrete and equipment to handle same.

The erection of the structural steel for the mill started with the digester and washer and screen rooms. These two buildings amounted to approximately 555 tons, being fabricated by Levinson Steel Co. and erected by Eichleay Corp. during the months of March and April, 1953. The remaining 7570 tons of structural steel for the building was supplied by Bethlehem Steel Co., who started erection during the month of June, 1953. By the latter part of October, 1953, all steel had been erected and bolted in all building areas.

Masonry work on the mill was started by the Southern Fireproofing Co. in the latter part of May, 1953, on the digester building and was substantially completed by March, 1954, with final completion of all masonry work by the middle of May, 1954. Exterior walls were 8 in. thick with 4 in. of brick and 4 in. of tile. Clear glazed tile was used on most operating floors, either of buff or green color; and on basement floors and above crane rails salt glazed tile was used. The total brick on the mill used in wall construction was in excess of 1,900,000 units. The tile amounted to over 862,000 units with 30,200 units of glass block and 8830 ft. of precast eaves being installed. U-drain tile, consisting of Stebbins reject tile, amounted to 45,094 units and jumbo brick used in U-drains amounted to 36,800 units.

The Eichleay Corp. was awarded a tonnage price contract for the erection of approximately 12,500 tons of equipment for use in the manufacturing of pulp and newsprint, recovery of chemicals, and handling of wood. The maximum sustained rate of equipment erection took place between the months of November, 1953, and March, 1954, at which time Eichleay averaged in excess of 400 tons per week as being erected.

Eichleay Corp. also had the contract for the erection of two power boilers, the bark burning boiler, and the recovery boiler on a lump sum basis. These boilers are not included in the total tonnage figured above.

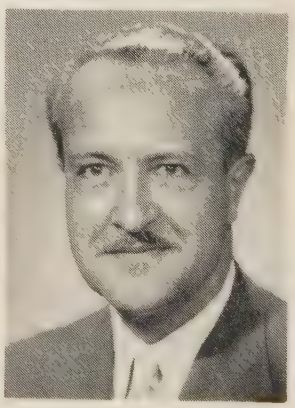
The erection of equipment in the wood preparation area began rather late in the year of 1953 and extended through May, 1954. This was one of the last areas to be started, mainly due to the extensive design and fabrication work which necessarily preceded the actual construction of the wood handling facilities. As a preliminary to work in the log pond area, Eichleay Corp. drove the sheet piling for the center caissons and the H-piling for the log pond bridge supports. Later they were awarded the contract for the construction of the wood unloading dock, which was started in May, 1954.

The W. L. Hailey & Co. of Nashville, Tenn., was awarded the contract for the 25,000,000-g.p.d. filtration plant, the 4,000,000-gal. reservoir, and the raw water pump house early in 1953 and started construction in February of that year, completing work in December, 1953.

The electrical work for the above area was completed in March, 1954, and this resulted in the complete water treatment system being the first portion of the mill to go into operation, which was early April.

The underground fire protection system and sprinkler system within the mill were installed by the Grinnell Sprinkler Div. Oman Construction Co. installed the remaining underground work consisting of the storm drainage, sanitary lines, and raw and filtered water supply lines to the mill.

Fischbach & Moore were awarded the contract for electrical work and actually began work on the job in February,



C. E. Opdyke, comptroller and treasurer

D. W. Timmis, secretary and assistant treasurer

1953. Grinnel Co. installed all process piping and began their work in March, 1953. The maximum force for Fischbach & Moore amounted to over 400, and for Grinnell Co. over 430.

Brice Building Co. of Birmingham, Ala., constructed the facilities building. This contract was awarded the latter part of April, 1953, and work started in early May. Bowaters personnel started to occupy the facilities building during the first part of April, 1954.

The maximum construction force during the job was broken down as follows:

J. E. Sirrine Co. Engineers	30
Fraser, Brace & Roane-Anderson, General Contractors	877
Subcontractors	1450

The general quantities of materials used in the project were as follows:

Concrete	65,300 cu. yd.
Brick	1,915,330
Tile	862,286
Glass block	30,165
Precast eaves	8,834 ft.
U-Drain tile	45,094
U-Drain brick	36,842
Reinforcing steel	2,853 tons
Structural steel	8,256 tons
Piles driven	6,099
Roof slabs and roofing	2,523,000 sq. ft.
Walkway slabs	6,284 sq. ft.

Associated architects, were Celli-Flynn of McKeesport, Pa., for the preparation of the architectural treatment of the mill and the design of the facilities building; also Willie Saint-Laurent of Montreal, Canada, acted as a consultant in respect to the wood handling.

Capacity

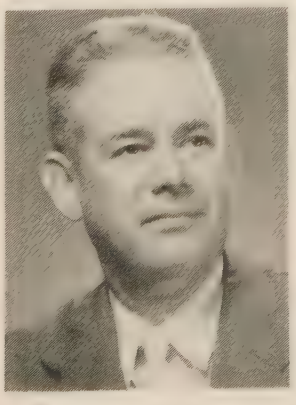
The initial design capacity is for the production of 125,000 tons of newsprint per year and 50,000 tons annually of either unbleached or bleached kraft pulp for sale.

The newsprint furnish requires daily approximately 360 tons of pine groundwood and 120 tons of bleached kraft pulp; with the total kraft pulp requirements, including that for sale, being approximately 312 daily tons.

The chemical consumption generally requires per day approximately 20 tons of salt cake, 8 tons of caustic, from 8 to 18 tons of chlorine, and 14 tons of lime. For the news furnish about 4000 gal. of 32° Baumé liquid alum is used, and 1200 gal. for water treatment; with required quantities of limestone, soda ash, and chemicals for slime prevention, color, etc.

The plant will have between 700 and 750 employees and at least an equivalent number will be employed directly or by

W. H. Joubert, traffic manager



E. L. Cowan, chief engineer

Interior view of filter plant which has a rated capacity of 25 million gal. per day

independent contractors for pulpwood production. Approximately three and one-half million dollars will be paid annually for wages at the plant; and a similar amount, or more, in connection with the wood supply.

Wood Handling and Preparation

A total volume of 906 cords of pine per day is used, shipped by river barge, railway, and trucks. Unloading of these carriers is accomplished as follows:

Adjacent to the river deck are, in order of their distance from the river, the following unloading facilities: a pivoted gantry crane which can be equipped with either an orange-peel grapple for unloading logs, a hook for handling slings of logs, or a clamshell bucket for unloading chips; a graded railway siding with car retarders to be used in properly spotting pulpwood cars by remote control; a pulpwood pit having a runway on which is placed an electric pulpwood rake to unload cars into the pit; and finally, space for a crawler crane equipped with an orange-peel grapple for use in periods of maximum wood shipments. A movable multiple-chain feeder receives wood from the crawler crane and feeds it onto the drum feed turntable.

Wood is unloaded from barges by the gantry crane and may be placed directly on a multichain feeder or into the pulpwood pit. Wood arriving in railway cars may be similarly unloaded, but is more rapidly unloaded into the pit by the pulpwood rake. Truck wood can be unloaded into the pit by means of either of the cranes or manually or onto the movable feeder by the crawler crane.

All wood placed in the pit is rehandled by the gantry crane or the crawler crane onto one of the two multichain feeders which drop the logs onto a revolving, elevated turntable used for final sorting of species and for feeding wood selectively to all or any of the three barking drums. This turntable, a flat ring in shape, is 60 ft. in diameter and 7 ft. wide, and runs continuously. Removal of wood from the table to the barking drum feed chutes is by means of hydraulically operated, remote controlled blades.

There are three suspended type barking drums, each 12 ft. in diameter by 45 ft. long. Dry method of barking is used, with the bark being removed by means of belt conveyors.

Unloading pulpwood at a yard of one of the rail shipping points in the North Georgia district. The Bowaters Woods Department has organized five districts in the Tennessee Valley area. The district forester is responsible for both procurement activities and the management of company lands within his district

Wood is fed from the barking drums to two parallel cable conveyors which run from the drums through the woodroom, to the center of a duplex storage pond. These conveyors have a figure eight arrangement in elevation so that wood loaded onto the lower strand at the drums arrives at the pond center on the top strand, and wood recovered from the pond and reloaded onto the conveyor starts on the lower strand and arrives at the top floor of the woodroom on the top strand. The duplicate arrangement of the pond and all equipment for storing and recovering wood is due to the necessity of keeping the wood prepared for the groundwood mill separate.

At the pond center wood is dumped from the cable conveyor to a 40-ft. diameter turntable, and thence is scraped onto a revolving stacking conveyer of special design which places the wood in a semicircular pile having a central radius approximately half that of the pond. The pond itself has a total volume under water for 30,000 cords. The recovery of wood from the pond is by means of duplicate pivoted gantry cranes, each equipped with a hoist, trolley, and special pulpwood grapple. Wood is placed by those cranes onto chutes at the center of the pond turntables, from which it is scraped off onto the lower strand of the appropriate cable conveyor. In addition to conveying the wood from drums to pond and from pond to woodroom, the cable conveyors serve as washing flumes to insure removal of residual bark and grit both prior to storing and upon removal from storage.

Wood arrives at the top floor of the woodroom on the two cable conveyors. Both conveyors unload onto a 40-ft. diameter turntable, but at different points on the circumference so that wood for mechanical pulp can be scraped off into a butting saw, and wood for chemical pulp can be scraped off into the chipper chute. The former operation is the first in the sequence, so that logs unfit for mechanical pulp can be allowed to pass on to the chipper feed point, or sent back to the barking drums by means of a belt conveyor. Logs for mechanical pulp having passed through the butting saw fall into a chute feeding a 1900-ft. long flume, which carries them to the grinder room where they are elevated from the flume to the apron conveyor feeding the grinders by means of two chain conveyors; the first of a special design for removing logs from water, the second to accelerate the logs and insure proper feeding to the apron conveyor.

For week-end operation when the drums are down, chutes are provided which will allow any partially barked or otherwise unacceptable wood to be sent back to the pond via the cable conveyors, from either the chipper feed point or from the butting saw table.

Wood for chemical pulp having passed through the chipper is fed by belt conveyor to a surge bin with star feeders and thence to a pair of chip screens. A uniform feed is accomplished by means of the star feeders. Oversize chips fall into a rechipper and are blown back to the surge bin. Fines are carried by a belt conveyor to a hog, which also receives the fines from the butting saw and the dry bark from the barking drums. After hogging, all of this refuse goes by conveyors past an emergency outdoor storage point to the power plant, where it is burned in a refuse boiler.

Accepted chips from the chip screens are carried by belt conveyors to the chip silos, where distribution into the three silos is accomplished by an enclosed scraper conveyor. Removal of the chips from the silos is by means of rotary plate feeders which discharge onto the first of two belt conveyors carrying the chips to the digesters. This conveyor carries the chips over a weighing device adjacent to the silos and discharges at the upper floor of the digester building onto a second belt conveyor, equipped with a tripper for feeding the digesters.

In addition to the equipment for handling pulpwood, a complete system for unloading purchased chips from barges and railway cars has been provided, beginning with a concrete pit into which chips can be placed by means of the crane and clamshell bucket, or dumped from hopper car which can be spotted over the pit, using a car shaker to assist unloading. The entire pit bottom is traversed by a drag chain which will carry chips to a belt conveyor, which in turn will place them in the surge hopper feeding the chip screens. Space for a continuous weighing device has been allowed on the run of the belt conveyor.

Digesters

For the daily production of 312 tons of raw kraft, there are five digesters, 11 ft. 6 in. i.d. by 43 ft. 3 in., of 3300 cu. ft. capacity; with space left in the building for a sixth. These digesters are of A-285 Grade "B" firebox steel and built in accordance with Paragraph U-200 of the 1949 ASME Code. Additional thickness of shell has been provided to resist corrosion. Each digester has a shell thickness of 2 in. and weighs approximately 62 tons. The digesters discharge through electrically operated blow valves through individual lines to a blow tank having a capacity for three blows.

The blow steam, after passing through a special cyclone in the head of the blow tank, goes to an accumulator and blow steam recovery system for the heating of the water.

R. B. Reid, purchasing agent

G. R. Koons, industrial relations manager

The relief steam from the digesters is carried to individual separators, thence to a relief cyclone, condenser, and decanter for the recovery of turpentine.

Wash Room

The stock from the blow tank is pumped through a specially designed trap to the preknotters and three 8 by 16-ft. vacuum-type washers. Space has been left in the washer building for the addition of a fourth washer in the future. The stock from the final washer is delivered by conveyor to a high density steel storage tank of 100 tons capacity, equipped with dilution nozzles and agitators at the bottom for the removal of the stock, the consistency of which is controlled at $3^1/_2\%$ by a pan-type regulator, discharging directly into an agitated surge and blending chest.

The drop legs from the washers discharge to a weak liquor tank, 30 ft. diameter by 35 ft., an intermediate tank 32 by 35 ft., and a strong tank, 34 by 35 ft. Three black liquor tanks, 25 by 30 ft., have been provided for storage. Adjacent to these storage tanks is a weak soap collecting tank with connections at various levels for laundering off any soap that would accumulate on the black liquor storage. The soap collected in this tank will be pumped at intervals directly to the soap storage tank. Foam lines from the liquor tanks go to a foam tower, 15 ft. diameter by 60 ft., on top of which is a foam breaker. In the strong black liquor filtrate tank a screw-type soap skimmer launders off soap and excess liquor, which discharges by gravity into the foam tank. Weak soap is separated here and also pumped to the soap storage tank.

The rejects from the preknotters discharge by gravity into a black liquor measuring tank, 9 ft. 6 in. diameter by 20 ft. high; provided with an agitator and a special pump so that the knots are returned to the digester with the black liquor fill. White liquor for the digesters is obtained by gravity flow from a tank 9 ft. 6 in. by 20 ft., set above the digester room floor, receiving its supply from the recausticizing plant storage.

The washers are mounted on the same floor level as the digester charging floor and are provided with hoods and exhaust fans. A 15-ton hand-operated crane serves the wash room.

Screen Room

The washed stock is pumped from the surge tank at ground level after the high density storage, to a consistency regulator and a primary constant level mix tank feeding two primary centrifugal screens; the accepted stock from which discharges by gravity to two 9-ft. 6-in. by 10-ft. valveless-type thickeners, and thence into a screened stock chest. The rejects from these primary screens discharge into a tank 8 by 18 ft., from whence they are pumped to another regulator and mix tank to a secondary screen. The accepted stock from this latter screen discharges into a tank, 8 by 18 ft., from where it is returned to the screened stock chest or directly to the pulp drier machine chest. The tailings from the secondary screen go to a secondary rejects tank, 8 by 18 ft.; from whence they are pumped through a magnetic separator, then to a drainer and a disk-type refiner, thence to the primary rejects tank for recirculation and rescreening in the secondary system.

The screens and equipment are located below the wash room operating floor in the same building.

A general view of the equipment for dumping wood in the storage pond and recovery of stored wood for use. In foreground is one of the two revolving stacking conveyors. In the upper left is shown one of the pivoted gantrys from which the grapples are suspended

Bleach Plant

From the screened stock chest in the wash room basement, as much pulp as it is desired to bleach is pumped at regulated consistency through brushing jordans to a tonnage control unit serving the chlorinators of a three-stage bleach plant.

The chlorination stage consists of a tile-lined steel tower, 18 ft. diameter by 61 ft. high, with two-tier arrangement of rubber-lined steel circulators and a rubber-covered skimmer to the launder at the top of the tower.

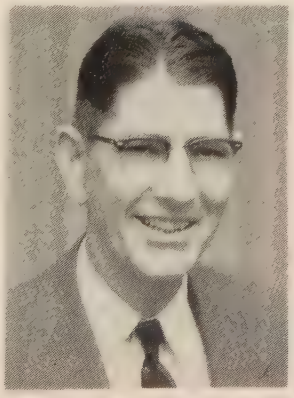
Chlorinated stock is pumped to an 8 by 14-ft. rubber-covered single valve vacuum washer, with shredder and conveyor for discharging through the high density double shaft mixer of cast iron to a caustic extraction tower of unlined steel, 10 ft. diameter by 47 ft. high; with one circulator of cast iron and 304 stainless steel construction.

Stock at the bottom of the caustic tower is diluted to about $2^1/_2\%$ consistency by nozzles for pumping to a cast iron single valve vacuum washer with shredder and conveyor for delivery at high consistency through a double shaft mixer to a steel, tile-lined hypochlorite tower, 17 ft. diameter by 17 ft. high, provided with two 304 stainless steel circulators.

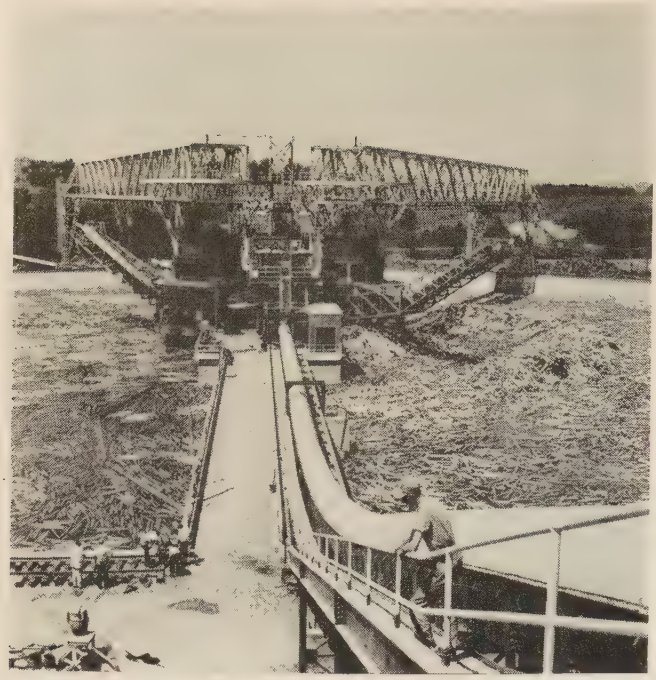
At the bottom of the hypochlorite tower, the high density stock is diluted by nozzles and pumped to an 8 by 14-ft. final vaccum washer with rubber-covered repulper, this washer being arranged for use with a future SO_2 stage, should the bleach plant be expanded.

Stock from the final washer passes through a pan type consistency regulator which discharges directly into an agitated low density tile storage tank, 16 ft. diameter by 18 ft. high, from whence it can be pumped either to the newsprint mill or to the pulp drier, as desired.

R. R. Edgar, woods manager



C. J. Maki, woodhandling and yard superintendent



The "log pond" at Bowater's Tennessee mills. In this great basin, measuring 500 ft. across the top, 30,000 cords of pulpwood are stored under water to prevent the rapid decay which would occur if stored on the ground. This great quantity of pulpwood is sufficient to meet the mills' requirements for a period of 6 weeks

The meter box, washer vats, and seal pits are all of structural tile construction.

The seal boxes are on the mezzanine floor, with all of the pumps for both stock and white water located in the basement.

The upper part of the building from the washer floor up is totally enclosed, pressurized to eliminate corrosion, with exhaust fans for the removal of vapors from the washers and towers. Filtered air is provided for air sweeping the instruments, motors, controls, etc.

The building has an elevator serving from the basement to the three upper floor levels, giving at the same time access to the brown stock washers and digester room floors.

Effluent from the chlorination and caustic stages is carried to a tile foam tower, which receives also exhaust fumes and foam from the seal pits.

A glassed-in partition on the operating floor encloses the control instruments, test laboratory, and office.

While the immediate plant is a three-stage for semibleach, full provision has been made for adding another caustic, hypochlorite, and SO_2 stage or for chlorine dioxide should the mill desire to manufacture full bleach.

Pulp Drier

For the drying of the unbleached or bleached pulp for sale, a combination high density feltless wet machine and a hot air drier is used.

The wet machine is of the two-press type with vacuum forming cylinder, 8 ft. diameter by 156-in. face, and three air-loaded press rolls. The first main press has a grooved cast iron top roll and bottom roll which is followed by a two-drum drier section, 60 in. diameter, and a second press similar to the first.

The drier built to trim 156 in. receives the pulp from the second press, with pinch rolls to feed it into the upper section of the drier which is divided into nine passes, with the exit at the bottom. Forty fans supply the necessary air circulation, with the heaters of the extended surface type and copper tubes.

The fresh air intake to the drier has filters to purify the make-up air, and fans have also been provided for cooling the vestibules. One 14-section economizer arranged for double-stage effect is mounted on the roof over the drier and supplies some water heating.

The wet machine and the conveyors of the pulp drier are driven by d.c. motors, with the several sections synchronized and receiving their current from a single motor generator set.

Equipment for cutting, laying, and conveying the pulp consists of a heavy duty cutter arranged to furnish from a 156-in. nominal trim five pulp sheets, $31\frac{1}{4}$ by $25\frac{1}{2}$ in., and three 47 by 53-in. wrappers; the cutter being driven by a d.c. motor in conjunction with the drier. Pulp coming from the cutter is delivered to the layboy of the heavy duty type, with the sheets carried on a series of narrow belts. The sheets are ejected from the tape unit to form vertical stacks, accumulated on the belt conveyor and lowering table. When the requisite number of shoots has been accumulated, the table lowers to its bottom position and discharges the stacks onto a conveyor, the table then raising to catch the pulp sheets accumulated during this operation on automatic fingers.

From the layboy, conveyors carry the stacks of pulp through a single downstroke baling press. The press platen is grooved so that stacks of pulp can be tied in the press. The conveying system as a whole comprises a 14-ft. swing section and storage belt with wrapper pickup, an air float scale section, and a hinged roller press discharge section; with a gravity roller conveyor to a lowerator stacker which delivers the bales to the basement onto a storage conveyor 30 ft. long.

A tile chest with a propeller type repulper receives wet broke from the wet machine, and a dry pulp broke disintegrater is installed in the basement at the cutter to receive dry broke.

A 20-ton manually operated crane serves the wet machine, and a small 5-ton crane the pulp cutting and handling equipment.

Storage for a minimum of 800 tons of pulp bales is available in the basement, from whence they are handled by lift trucks to a train shed for shipment.

Groundwood

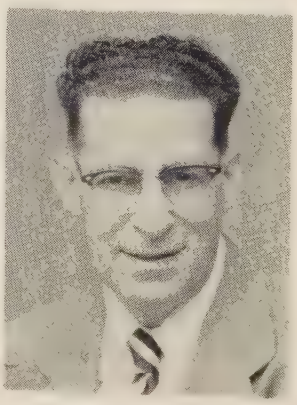
Logs for the groundwood mill are delivered from a water flume conveyor to inclined chain conveyors, discharging onto a flat steel apron charging conveyor to the grinders.

For preparation of groundwood there are eight grinders, complete with governors and hydraulic control equipment. Each of these grinders is driven by a 4500-hp. synchronous motor, equipped with water coolers.

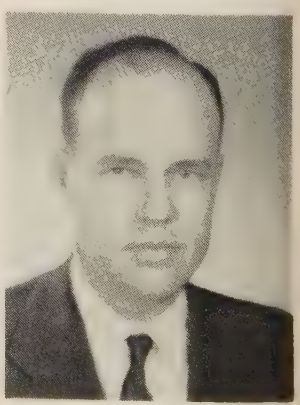
There are two 20-ton cranes; one for servicing the grinders and the other for the grinder motors.

A vapor exhaust system is provided for the grinders and the grinder flumes.

The groundwood stock preparation equipment consists of



J. J. Moynihan, groundwood superintendent



T. C. Bannister, sulphate superintendent

two bull screens, consistency control equipment, four primary centrifugal screens, and one secondary centrifugal screen.

A hammermill breaks up bull screen rejects. For further treatment of these rejects and the screen tailings, three drainers and disk refiners are provided.

Ten 12-in. primary Dirtec and ten 4-in. secondary Dirtec units remove the shives and dirt from the groundwood pulp. Six groundwood deckers thicken the stock after the Dirtecs for storage.

Stock Preparation

There are two lines of equipment in the stock preparation room for supplying refined bleached kraft furnish to the paper machines; one line supplying each machine. Refining of bleached kraft is accomplished by four jordans. One small broke jordan is provided for each paper machine, and one 11-ft. 6-in. diameter by 16-ft. vacuum saveall clarifies the white water and thickens the broke from each paper machine.

All stock and white water chests and the saveall vats are constructed of reinforced structural tile, equipped with propeller agitators.

Metering of groundwood, bleached kraft, and broke in proper quantities is accomplished through proportioneering equipment.

Paper Machines

Ahead of each paper machine there are five screens and one vibrating rejects screen for final screening of stock.

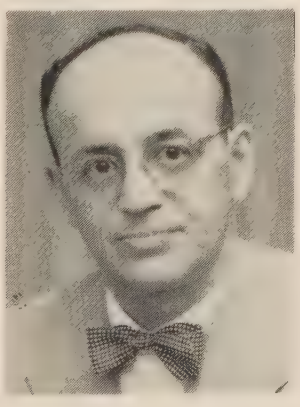
There are two 252-in. newsprint machines, designed for speeds up to 2000 f.p.m. Stock and color are metered to a 12,000-g.p.m. fan pump supplying the screens. Dilution water for this stock is obtained from the fourdrinier savealls that discharge into a tile collector chest. Screened stock is then collected in a deaerating flume and is further diluted prior to being pumped by a 17,000-g.p.m. fan pump to the pressurized type headbox, with slice of latest design. The fourdrinier has a 252-in. wide by 116-ft. long wire and is complete with table rolls, suction boxes, and savealls for separating the wire drainage from the wire shower water.

The press section consists of automatic suction pickup roll, a suction transfer press, wringer roll, and two straight through suction presses. The drier section consists of 55 60-in. diameter paper driers and 11 60-in. diameter felt driers, divided into four sections. The calender stack is the open type, complete with eight rolls. The reel is the heavy duty type, equipped with the latest design of reel brake. The winders are high speed design, complete with shaft puller and roll lowering table.

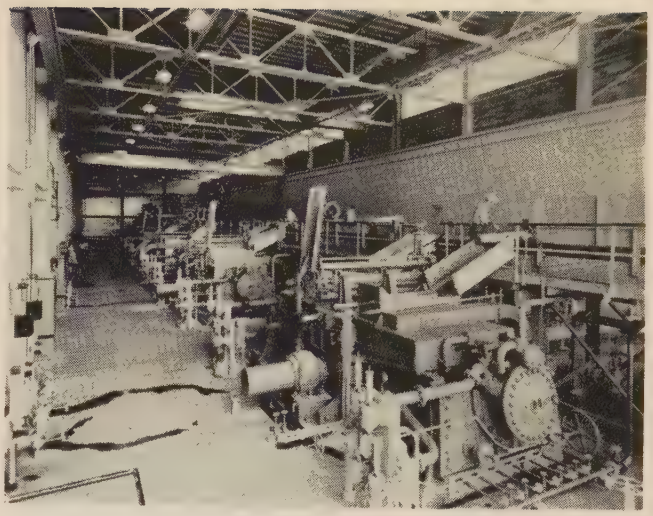
The newsprint machines are driven by electric sectional drives and are complete with drier drainage equipment and a Crowin system.

The paper machine vacuum equipment for the couch roll, suction boxes, presses, transfer equipment, and felt conditioners consists of three H-12A, two L-11A, and two K-10A vacuum pumps.

V. J. Parson, paper mill superintendent



J. N. Swartz, technical service superintendent



A general view of the grinder room. Four grinders are installed on each side of the conveyor. All grinder pockets are accessible from the one wood conveyor

The wire and couch pit is of special design and wet broke from the couch flows directly into a tile chest equipped with breaker agitation equipment. This chest also handles the press broke delivered by a conveyor from the presses.

A broke disintegrator is provided at the dry end of each paper machine for handling broke and winder trim. The discharge from this broke disintegrator is controlled through extractor plates and dilution is controlled by pressure-type consistency regulators.

The paper machines are equipped with transite hood and felt drying systems. Latest improvements in air makeup, heating and ventilating, motor cooling, and trim conveying systems in the machine room and also the stock preparation room have been incorporated.

A large machine room crane is provided for servicing the two paper machines and on each machine there is an individual electric crane for transferring rolls from the reel to the winder.

Newsprint rolls are discharged from the winder onto floor type transfer conveyors, where they are rolled into an automatic roll wrapping machine. From the roll wrapping machine the rolls go directly to two roll headers, each equipped with scales. Rolls then go to an 18-hr. storage space on the second floor. A conveying system conveys and lowers rolls from this storage on the second floor to either the storage below or to a car loading conveyor running the full length of the shipping platform. The floor and platform conveyors are floor flush type and rolls can be rolled off at any desired place for loading to railroad cars by fork trucks. Storage for a minimum of 1800 tons of news rolls is available in the basement, as well as facilities for loading trucks for local shipment.

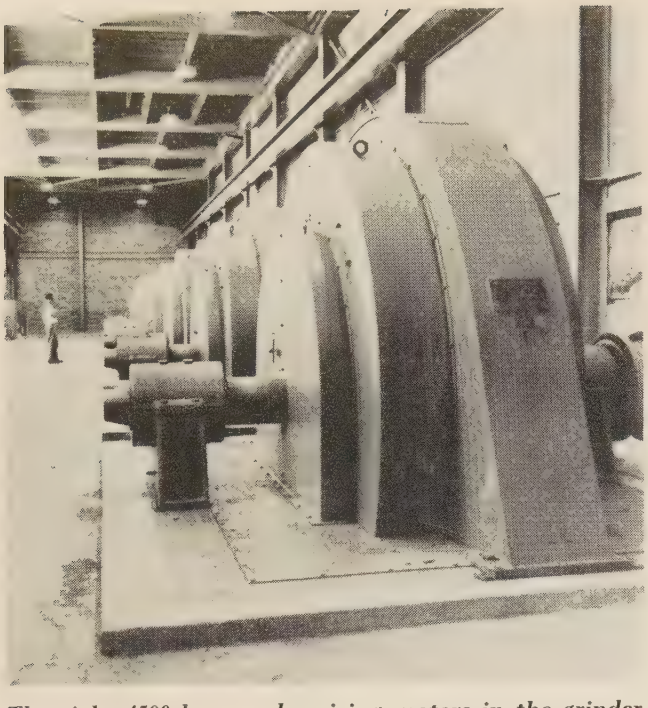
Power Plant

To supply the steam requirements of the mill and 20,000 kw. of its electrical requirements, a topping cycle has been chosen for the power plant. Basically the plant operates on a regenerative 2-heater cycle, with make-up varying between 20 and 50%.

Steam Generators

A careful economic study of the proper primary steam pressure and temperature resulted in the selection of 875 p.s.i.g. and 825°F. One of the limiting factors in the determination of this pressure is the location of the mill in the low cost TVA power region.

Steam at this pressure and temperature is produced in one recovery boiler, one bark burning boiler, and two power boilers.



The eight 4500-hp. synchronizing motors in the grinder motor room

The recovery boiler has a 24-hr. dry solids capacity of 950,000 lb., or an average steam production of 123,200 lb. per hour. A twin electric precipitator is located at the discharge of the i.d. fan.

The bark burning boiler is capable of producing 125,000 lb. of steam per hour, with either bark or natural gas firing. Under normal anticipated conditions there is enough bark to maintain about a 68,000 lb. per hour steam load. Only when one of the power boilers or the recovery boiler is out of service is it necessary to fire natural gas in the bark boiler for additional steam. This boiler is equipped with a traveling grate and spreader stoker for the bark, and tangential burners for the natural gas. The boiler section is of the straight through no-baffle type.

In front of the bark boiler above the firing aisle is a bark storage bin of 6000 cu. ft. capacity. Bark is fed from this bin into the spreaders by screw conveyors placed across the bottom.

Each of the power boilers is of 150,000 lb. per hour capacity, fired primarily by natural gas, with provision for bunker "C" fuel oil firing during periods of natural gas shortage. Under normal circumstances these boilers share whatever load is required in excess to the bark and recovery production. In laying out the auxiliary equipment for these units, provision has been made for the possible future addition of coal bunkers and pulverizers. The furnaces are provided with hopper bottoms to permit the use of pulverized coal without changes to the unit proper.

A complete fuel oil burning system is provided for secondary fuel operation of the power boilers. This includes a main oil storage tank, a day tank, an oil pumping and heating set, and the necessary oil guns.

Turbo Generators

In order to obtain topping power from the process and heating steam, two turbogenerators of 10,000 kw. capacity each were chosen.

Turbine 1 has throttle conditions of 850 p.s.i.g. and 825°F., automatic extraction at 50 p.s.i.g., and a condenser for $2^1/_2$ in. Hg.

Turbine 2 has the same throttle conditions, with automatic extraction at 150 p.s.i.g. and 50 p.s.i.g. back pressure.

Steam Distribution

Two steam pressure levels are needed for the mill facilities. They are 150 and 50 p.s.i.g. Extraction and exhaust steam taken from the turbines is fed to 150 and 50-p.s.i.g. headers, respectively. From these headers steam is taken for the mill and for whatever station service is required. Desuperheaters are located in the mill take-offs to reduce the temperature to just above saturation.

Linking the 850, 150, and 50-p.s.i.g. headers are lines containing PR stations. These by-pass lines are for the purpose of insuring flexibility under any foreseeable conditions.

Within the power house there is a 5-p.s.i.g. header, with a by-pass connection from the 50-p.s.i.g. header. Steam for the No. 1 feedwater heater is taken from this 5-p.s.i.g. header.

Feedwater System

Make-up water is added to the condensate storage tank along with the mill returns and condenser hot well returns. The make-up varies between 20 and 50% of the total feedwater flow, depending on the operating conditions.

A condensate pump (with a standby pump) takes water from the condensate tank and pumps it to the deaerating heater which operates at 5 p.s.i.g. This heater is of the horizontal, tray type, capable of reducing the oxygen content to 0.005 cc./liter.

Water at approximately 228°F. leaves the deaerating heater and falls to the boiler feed pumps. The feedwater pump raises the water pressure to approximately 1080 p.s.i., which is sufficient to carry the water through the no. 2 heater (closed type), through the feedwater control valves and into the boilers.

The no. 2 heater receives steam from the 50 p.s.i.g. header in order to heat the feedwater to 280°F. The condensate from this closed heater is discharged directly into the open heater.

The feed pump station consists of three identical pumps, each rated at 1200 g.p.m. and 2500-ft. head. The principal pump is driven by a steam turbine and an electric motor. The other pumps are motor driven only and intended for standby service.

The turbine drive for the feed pump receives steam from the 150 p.s.i.g. header and discharges it to the 5 p.s.i.g. header, which in turn supplies steam to the open heater. A back pressure regulator controls the flow of steam to the turbine, which varies the amount of pump load that the turbine can handle.

To keep the pump up to speed, the motor connected to the other extended shaft of the pump takes up the remainder of the load. Normally, this motor drive is lightly loaded or just floating on the shaft, but whenever the flow of steam to

Otha Winningham, mechanical superintendent

M. J. Osborne, electrical superintendent

the deaerator falls below that required for full pump power, the motor picks up load.

The feedwater flow includes that which is necessary for steam production, plus approximately 1% for continuous blowdown. The blowdown is flashed at 50 p.s.i.g. This flash steam is piped into the 50 p.s.i.g. header.

Air Compressors

To supply mill and station compressed air, two compressors are installed. One of these is in the turbine room and the other in the mill. These compressors operate at approximately 110 p.s.i.g. and supply all of the plant's service air requirements.

A recovery air compressor is located in the turbine room for use by the recovery boiler air soot blowers. This compressor discharges at 350 p.s.i.g. and has a storage tank of suitable volume to permit full extension and retraction of any one of the IK blowers.

For instrumentation air, one instrument air compressor is located in the turbine room and two in the machine room. The compressor receivers are joined by a suitable pipe so that all three are available for either mill or power instrument use. On the outlet connections of these receivers are air driers. The instrument air compressors are of the "carbon ring" type so as to not introduce oil into this system.

Controls

The control of the recovery boiler is essentially manual with the exception of a furnace draft control which operates the induced draft fan hydraulic coupling. The rapping cycle of the electric precipitator is automatically controlled.

The bark boiler is fired by manually controlling the feeder screws. An oxygen recorder is used to assist control of the amount of overfire air, and a furnace draft controller regulates the induced draft damper.

In addition to the above controls the bark boiler has air flow-gas flow controls for the firing of natural gas from the tangential burners.

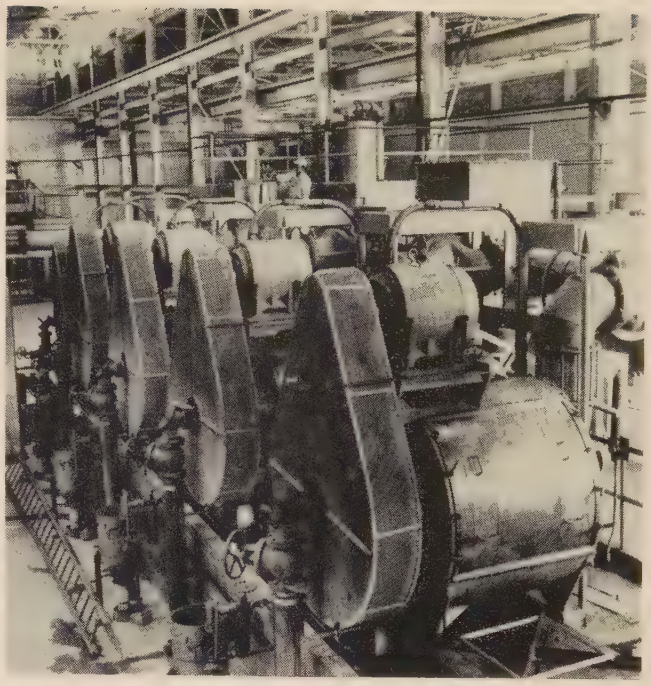
The power boilers are primarily controlled by a steam pressure controller which operates by main steam header pressure. This enables the power boilers to produce whatever steam is required above the production of the recovery and bark units.

The power boilers have automatic controls for the firing of natural gas, and remote manual controls for firing bunker "C" fuel oil.

All of the steam generators in the plant have automatic three-element feedwater controls.

Electrical Equipment

For full scale production of the mill approximately 37,000 kw. of electric power is required, which includes 20,000 kw. for the wood grinding operations. This is obtained from the two turbogenerators operating at their rated output, supplemented with 17,000 kw. from the TVA system. Normally the turbines operate in parallel with the TVA system, but the electrical system is arranged for independent operation with the power from the TVA system being utilized in the groundwood area, and the turbogenerator output in the rest of the mill. In addition, capacity has been provided in the TVA facilities to permit full scale operation of the mill with one of the generators out of service.



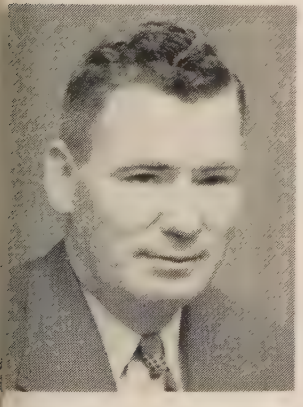
The four primary centrifugal screens in the groundwood mill

Electric power at 13,800 volts, 3 phase, 60 cycles, is distributed throughout the mill to the various load centers for conversion to utilization voltages. The power supplied by the TVA system is delivered to the grinder room substation where through two 15,000-kva., 3-phase transformers, 4160 volts is made available for eight 4500-hp. unity power factor synchronous motors driving the grinders; and through two 750-kva. unit substations, 460 volts is made available for auxiliary equipment motors. The power generated with the two 10,000 kw. turbogenerators is distributed at 13,800 volts to the woodyard, pulp mill, bleaching, stock preparation, and machine room areas, where it is transformed to 460 volts for motors up to 200 hp., and 2300 volts for motors 201 to 1000 hp. capacity. The two turbogenerators and the TVA system are interconnected through a synchronizing bus, with complete system control located in the power plant.

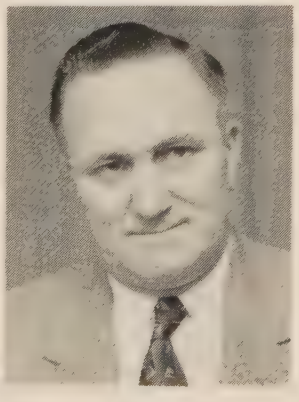
The primary control equipment is arranged for simplicity and convenience of operation as well as for safety of personnel, together with provision for isolation of power sources and sectionalizing of the load for other than normal operating conditions. The arrangement is flexible in that it readily permits inclusion of necessary controls for additional power sources and load whenever required.

Primary control equipment was selected on the basis of continuous current rating together with the short circuit kva. available at the point of utilization; and the whole coordinated to a 500,000-kva. level. This coordination was extended in the selection of unit substations to permit the use of 150,000-kva. high interrupting capacity motor starters for the 2300-volt motors, and combination magnetic starters in motor control centers for the 440-volt motors.

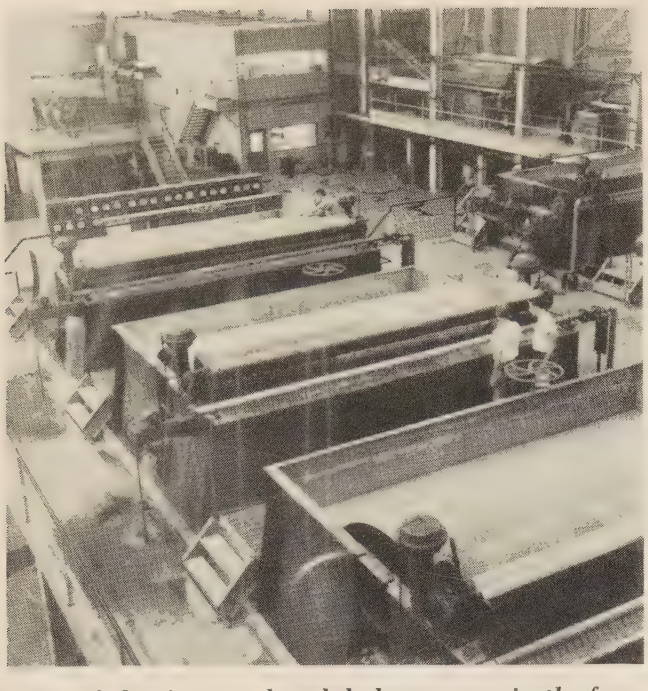
Use of unit substations together with low voltage motor control centers practically eliminates any low voltage power distribution. In the case of 2300-volt equipment, the motor



R. R. Streety, power and steam superintendent



R. L. Martin, finishing and shipping superintendent



Three of the six groundwood deckers appear in the foreground with a portion of the stock preparation control panels immediately behind the deckers

starters form the low voltage section of the substations; hence the motor loads constitute the 2300-volt wiring. For the 440-volt wiring, there are only short stub feeders to the motor control centers, and the motor loads make up the balance. Local control of the motors is accomplished with push button stations placed at the machines with the individual starters in isolated control rooms along with the unit substations.

Motor applications throughout the plant are in general of the conventional type and require only standard equipment. However, the grinder motors are enclosed with built-in air coolers, and each of the paper machines is driven with an electronically controlled adjustable speed variable voltage sectional drive, including multiple generator motor generator sets, and 500-volt d.c. adjustable speed, enclosed separately ventilated section motors.

The plant lighting system is sectionalized according to departments and locally controlled. In some areas mercury-vapor filament combination luminaries are used, and in others filament type units; depending upon the process, atmospheric, and structural conditions. Power for the plant lighting is obtained from the 750-kva. unit substations of the general power system and distributed at 460 volts to the area centers, where it is transformed to 115/230 volts for the lighting units. Illumination intensities vary in different parts, but are commensurate with the requirements of each area.

Recovery

For the evaporation of the surplus black liquor from the kraft mill, a six-body, sextuple effect evaporator has been installed. The unit has sufficient capacity to evaporate 173,000 lb. of water per hour; with 34,500 lb. per hour of steam at 35 lb. gage.

To condense the vapors from the sixth effect, a surface condenser of the vertical type is used, and consumes 1800 g.p.m. of 70° water, with a temperature rise to 110°. A soap skimming tank with a paddle type mechanical skimmer removes the soap from the liquor between the third and fourth effects.

The chemical recovery unit for the burning and reducing of the dry solids contained in the black liquor has capacity sufficient to burn 950,000 lb. of solids per 24 hours; with a steaming capacity of 123,200 lb. per hour at 875 p.s.i. and 825° from the feedwater at 280°.

Preliminary evaporation on the unit is through a cascade evaporator, with wheels 14 ft. diameter by 9 ft. 6 in. face. Both f.d. and i.d. fans are driven by motors, the latter having a hydraulic coupling for speed control.

For soot blowing, an air puff system has been furnished for the collector zone and the economizer passes, consisting of 16 heads automatically controlled for sequential operation. In addition there are 12 retractable soot blowers for the clearing of the screen tubes and superheater elements, all arranged for double side installation at six locations. These units are air operated with superheated steam for the cleaning medium.

For the handling of salt cake a pneumatic system is used to unload cars and deliver either into storage or the feed hopper of the unit.

For the recovery of salt cake and dust in the flue gases, an electric precipitator is furnished and installed as an integral part of the recovery building above the cascade evaporators. The unit consists of two electrical precipitators enclosed within a shell structure of combined hollow tile, steel, and reinforced concrete. Each of these units has an individual stack and is so arranged that with one of the units down, the other can still be maintained in operation.

The recovered salt cake from the precipitator is collected and dissolved in four wet bottom pans through which concentrated liquor is circulated and its chemical strength built up.

Causticizing

The causticizing plant consists of the following conventional systems: green liquor clarification, dregs washing, lime slaking, white liquor clarification, and lime mud washing. The design capacity is 30,200 cu. ft. per day of white liquor, with 8 lb. per cubic foot of total alkali and 7 lb. per cubic foot of active alkali, all expressed as Na_2O with a sulphidity of 30%. The plant can be operated up to a capacity of 38,000 cu. ft. per day. The white liquor clarifier and lime mud washer are of the multiple tray type, while the green liquor clarifier and dregs washer are of the single tray type.

Lime Reburning

The lime reburning plant consists of a rotary lime kiln, 9 by 250 ft., with four supports. At the feed end, a vacuum mud filter and a slurry feeder provide a constant rate of feed. Fuel for the kiln is natural gas. The design capacity of the kiln is approximately 80 tons per day. The kiln can be operated up to a capacity of approximately 125 tons per day to handle peak loads and additional production. Limestone is used as make-up and is introduced by a table type feeder to the kiln feed conveyor. The limestone is stored in an overhead storage bin with a capacity of 47 tons, and provision has been made for a ground storage of approximately 100 tons. The limestone system consists of a track hopper, drag chain conveyor, bucket elevator, and necessary chutes.

Water Supply and Treatment

The raw water for plant uses is obtained from the Hiwassee River, about two and one-half miles above the plant site. Vertical submerged type raw water pumps are installed, three pumps being used for the initial installation. These pumps have a capacity of 6000 g.p.m. each, or a total of 18,000 g.p.m. The raw water is pumped through 12,000 ft. of 36-in. steel pipe, lined and coated, to a treating plant located on a hill above the plant site. The treating plant is a modern gravity type filtration plant utilizing flash mixing, mechanical flocculation, settling and rapid sand filters. The clear well for the plant consists of an open, sloping side, concrete-lined reservoir with a capacity of four million gallons.

The rated capacity of the water treatment plant is 25 million gallons per day.

The lower section of the clear water storage reservoir is

reserved for fire protection. Due to the elevation of the clear water reservoir, a gravity flow is obtained to the mill; consequently, no service water pumps are required at the treating plant.

Waste Disposal

The waste disposal system for the mill consists of a pump house for elevating the process waste to a primary settling basin. Secondary treatment is obtained in a large disposal reservoir with a detention capacity of approximately 24 days for the entire mill process waste. The sludge from the primary settling basin is pumped to a permanent disposal area of 25 acres, located in a ravine on the mill property. The primary settling basin for the disposal plant consists of an earth lined reservoir, sloping sides, with mechanical rotary type sludge collector. The system is laid out for an addition of future units in the event the mill capacity is later increased.

Piping and Instruments

Plain black steel pipe is used through the digester, wash room, and recovery area; also for the feedwater and hot condensate service.

In general, transite pipe is used for all stock and white water piping after the washed stock storage chest, and for the groundwood and stock furnish up to the metering stuff boxes of the paper machine. From the metering stuff boxes to the machine and for the overflow from the screens, the pipe is stainless steel.

For the chlorination stage of the bleach plant, rubber-lined pipe is installed. For the caustic stage black steel pipe is used; and for the hypo stage, stainless steel.

For throttling and shutoff service on stock lines, Ferguson and Saunders-type valves have been provided; on black liquor in the washing and digesting system, lubricated plug cocks and stainless trim gate valves; and for white water in the machine room, all-bronze or stainless steel gate valves.

The mill is adequately supplied with control instruments. In general, the controls for the various divisions of the plant are mounted on panels centrally located on the operating floor in each building.

Buildings

All manufacturing buildings conform to the following general types of construction:

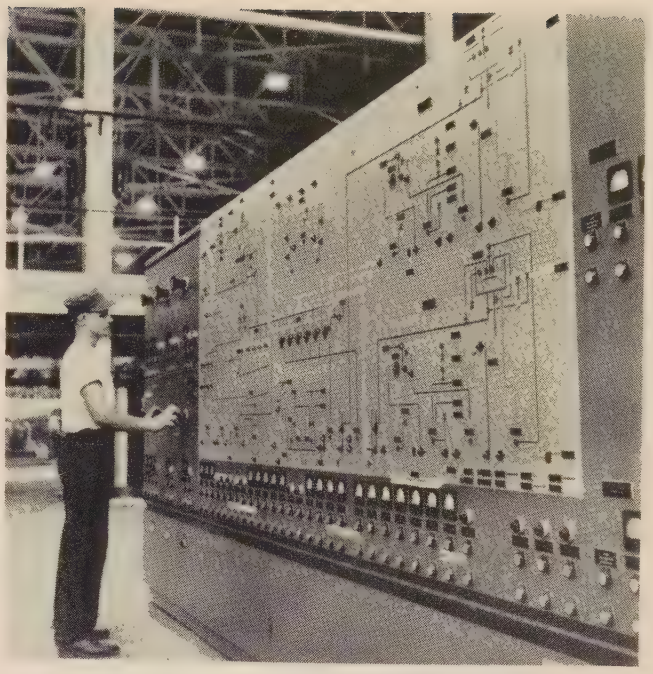
Foundations are cast in place, concrete piles, 40 ton capacity, with reinforced concrete pile caps, piers, and grade beams. Lighter structures, tanks, etc., have been placed on reinforced concrete spread footings with soil value 2500 to 3000 per sq. ft. Approximately 7200 piles were required.

Building frames are of structural steel, connected with high tensile strength bolts. Approximately 8000 tons were required for buildings and major structures.

For the roof, level precast concrete slabs were used; 20-year built-up roofing, interior conductors with provision to maintain 2 in. of water on roof surface for Summer insulation. Paper machine, pulp drying, and stock preparation rooms also have 2-in. rigid insulation.

Exterior walls of all manufacturing buildings are red common brick, with small amount of yellow. Exterior of facilities and administration buildings are yellow common brick, with small amount of red.

To enhance the appearance of the mill, color dynamics have been applied to a considerable extent, particularly on equipment where there are about 17 different color schemes which follow generally a safety code pattern with distinctive shades for various portions of the mill, moving parts, etc. In conjunction with this, several shades of interior tile have been used. The basic interior color of the walls is formed by the use of buff salt glazed tile. The main machine room walls, however, are buff ceramic glazed tile with contrasting areas of green. These basic colors are used also in the other sections of the mill, forming either a basic green area relieved by buff, or a basic buff area relieved by green. The power plant is treated in a similar fashion, with a basic green ceramic tile for the walls. Structural steel column flanges and like portions of the building actually forming part of the wall surfaces have been painted to match the tile areas. Exposed structural steel throughout the main mill has in general been painted yellow to blend with the basic tile colors.



Semi-graphic control panel in the stock preparation room

Continuous belts of glass block are used beneath eaves and wherever else required for lighting, with small vision panels at eye height at selected points. Continuous belts of adjustable aluminum louvers are used for ventilation. Large areas of ventilated corrugated glass top hung sash are featured in the grinder room and recovery room.

Floors are reinforced concrete or welded steel gratings, depending on use and occupancy.

Four elevators are provided. These are in the recovery room, the bleach plant, the shops and stores building, and the shipping and storage building.

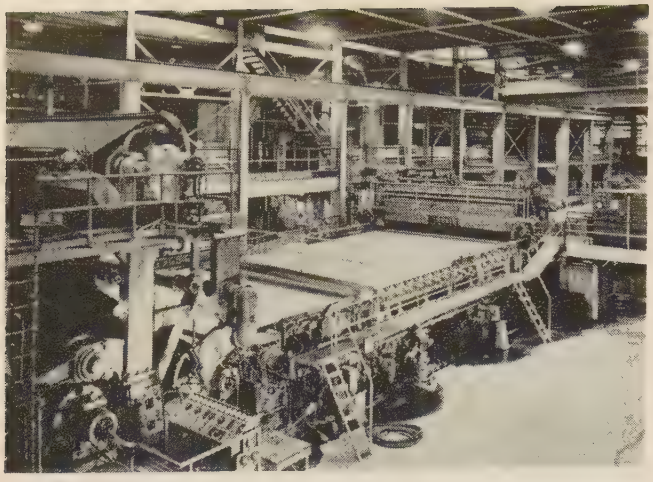
The main manufacturing buildings are approximately 1200 ft. long and cover approximately six acres under roof, enclosing about thirteen million cubic feet of space. The power plant group is approximately 200 ft. square and covers about one acre under roof, enclosing about three million cubic feet. The highest structures are the recovery room, approximately 115 ft. above grade; and the bleach plant, about 95 ft. above grade.

The main mill buildings which face toward the highway are treated with red brick, buff brick, and corrugated glass panels and glass block to enhance the architectural effect, with an illuminated Bowaters sign and insignia surmounting the center of this group.

General Facilities

A two-story building for shops and stores is located on one side of the grinder and stock preparation rooms parallel to the servicing tracks. The upper floor with about 20,000 sq. ft. is used as the shops, and the basement with the same area for stores. At one end of this building where access is available by cranes from the machine room there is a roll grinder, 42 by 280 in.; provision also being made at the same point for loading out to cars by overhead crane. An 8000-lb. elevator serves this building.

Adjacent to the utilities building is a paved parking area



View of the wet end of no. 1 newsprint machine. At the extreme right can be seen the control panels installed on a flying bridge operated between the headboxes of the two machines

of approximately 300,000 sq. ft., sufficient to take care of 600 employees' cars.

Mill offices of glazed tile are mainly located at one end of the shops and stores building where they are central to the mill. There are other offices on the mezzanine floor at the finishing end of the machine room.

A laboratory of glazed tile is located at one end of the stock preparation room adjacent to the main mill entrance and on the second floor.

The main utilities building of about 12,000 sq. ft. is adjacent to the main entrance road and gate, and provides facilities for watchmen, first aid, reception room, credit union, personnel office, time and payroll offices; also a main locker room of tile with provision for 50 foremen and 710 production and maintenance employees. Part of the utilities building houses a cafeteria, with a large conference room adjoining it.

The mill area as a whole is enclosed with cyclone fencing, requiring approximately 9000 lin. ft.

The Southern Railway serves the site with a spur track about 1500 ft. long from their main mill line near Calhoun to the mill gate. There are approximately 18,000 ft. of track inside the mill area for servicing the plant.

A complete system of underground storm drainage has been provided, with a separate sanitary system and process waste disposal as already mentioned.

Drinking fountains are located throughout the mill, the supply being taken through a separate line from the filter plant, with provision for chlorination. There is a separate compartment in the standpipe at the filter plant for storage of this drinking water.

For mill communication there is a 55-position switchboard for outside telephones; also an inter-mill dial system.

For warehousing, five butler buildings, each 40 by 100 ft. have been erected for permanent storage and were supplemented by five additional units for temporary construction purposes, giving a total of 40,000 sq. ft. of storage. In addition to this there are two 40 by 100-ft. butler buildings at the entrance road which served as temporary Bowaters engineering and construction offices. These offices are being used by Bowaters on a semipermanent basis until their main administration building is completed.

—History and Mill Description by D. G. Moon and staff, J. E. Sirrine Co., Greenville, S. C.

Officers of Bowaters Southern Paper Corp.

President	Sir Eric V. Bowater
First Vice-President	A. B. Meyer
Vice-President and General Manager	K. O. Elderkin
Treasurer	C. E. Opdyke
Secretary	D. W. Timmis
Assistant Secretary	James G. Cate, Jr.

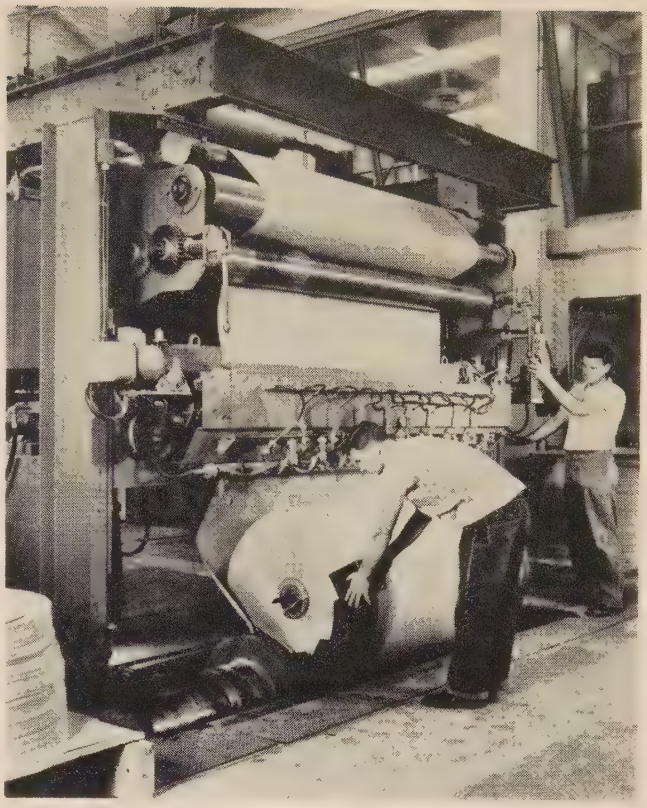
Key Personnel List—Bowaters Southern Paper Corp.

K. O. Elderkin	Vice-President and General Manager
V. J. Sutton	Mill Manager and Assistant to General Manager
C. E. Opdyke	Comptroller and Treasurer
D. W. Timmis	Secretary and Assistant Treasurer
R. R. Edgar	Woods Manager
G. R. Koons	Industrial Relations Manager
R. B. Reid	Purchasing Agent
W. H. Joubert	Traffic Manager
E. L. Cowan	Chief Engineer
W. J. Parson	Paper Mill Superintendent
T. C. Bannister	Sulphate Superintendent
J. N. Swartz	Technical Service Superintendent
Otha Winningham	Mechanical Superintendent
R. R. Streety	Power and Steam Superintendent
J. J. Moynihan	Groundwood Superintendent
R. L. Martin	Finishing and Shipping Superintendent
C. J. Maki	Woodhandling and Yard Superintendent
M. J. Osborne	Electrical Superintendent

Principal Suppliers of Mill Equipment Bowaters Southern Paper Corp.

Allis-Chalmers Mfg. Co., Milwaukee, Wis.—Vibrating Screens, Pumps and Texrope Drives
American Meter Co., Inc., Philadelphia, Pa.—Meters
American Monorail Co., Cleveland, Ohio—Ash Handling System
Appleton Machine Co., Appleton, Wis.—Centrifugal Pulp Screens, Rewinder
Askania Regulator Co., Chicago, Ill.—Consistency Regulators
Bailey Meter Co., Cleveland, Ohio—Combustion Control
Beloit Iron Works, Beloit, Wis.—Newsprint Machines, Winders
Bird Machine Co., South Walpole, Mass.—Bird Screens, Dirtecs
Bristol Co., Birmingham, Ala.—Instruments
Bristol Metal Products Corp., Bristol, Tenn.—Miscellaneous Tanks and Chutes
Brooks Equipment & Mfg. Co., Knoxville, Tenn.—Load Lugger
Broughton, A. R., & Co., Glens Falls, N. Y.—Vacuum Control Systems
Buckman Laboratories, Inc., Memphis, Tenn.—Slime Measuring Units
Carolina Steel & Iron Co., Greensboro, N. C.—Turntables
Carthage Machine Co., Carthage, N. Y.—Chipper
Chain Belt Co., Milwaukee, Wis.—Log and Chip Conveyors
Chattanooga Boiler & Tank Co., Chattanooga, Tenn.—Miscellaneous Tanks, Boxes, and Chutes
Chicago Bridge & Iron Co., Chicago, Ill.—Shop Built and Field Erected Tanks
Cochrane Corp., Philadelphia, Pa.—Demineralizer, Blow-Off Equipment
Coen Co., San Francisco, Calif.—Pump Sets
Combustion Engineering, Inc., New York, N. Y.—Power Boilers, Bark Boiler, Recovery Furnace
Continental Equipment Co., Coraopolis, Pa.—Valves
Daniel Orifice Fitting Co., Houston, Tex.—Orifices
DeLaval Separator Co., New York, N. Y.—Oil Purifiers and Paper Machine Oil System
Dempster Brothers, Knoxville, Tenn.—Carloaders
Despatch Oven Co., Minneapolis, Minn.—Oven
deZurik Shower Co., Sartell, Minn.—Consistency Regulators
Dings Magnetic Separator Co., Milwaukee, Wis.—Chip Magnets
Dixie Mill Supply Co., Inc., New Orleans, La.—Machine Tools
Dorr Co., Stamford, Conn.—Causticizing Equipment, Clarifier
Duriron Co., Dayton, Ohio—Hydraulic Ejector, Pumps
Earl Paint Co., Utica, N. Y.—Tank Insulation and Protective Coating
Eastwood-Nealley Corp., Belleville, N. J.—Suction Box Conditioner
Elliott Co., Charlotte, N. C.—Strainers
Equipment, Inc., Atlanta, Ga.—Vertical Pumps
Equitable Equipment Co., New Orleans, La.—Stacks and Breeching, Miscellaneous Tanks
Eriez Mfg. Co., Erie, Pa.—Pressure Magnetic Humps
Fairbanks-Morse & Co., Chicago, Ill.—Pumps
Falk Corp., Milwaukee, Wis.—Motoreducers
Farrel-Birmingham Co., Inc., Ansonia, Conn.—Roll Grinder
Fibre-Making Processes, Inc., Chicago, Ill.—Barking Drums
Fischer & Porter Co., Kingsport, Tenn.—Instruments
Foster-Wheeler Corporation, New York, N. Y.—Blow Heat and Turpentine Recovery Systems
Foster & Woods, Inc., Nashville, Tenn.—Chip Blowing System
Foxboro Co., Foxboro, Mass.—Instruments

Fuller Co., Catasauqua, Pa.—Airveyor Systems
General Electric Co., Chattanooga, Tenn.—Motors, Cable, Transformers, Paper Machine Drives, Turbogenerators, Control Equipment
General Railway Signal Co., Rochester, N. Y.—Track Retarders
General Steel Tank Co., Inc., Birmingham, Ala.—H_2SO_4 Tank
Goslin-Birmingham Mfg. Co., Inc., Birmingham, Ala.—Evaporators
Graver Water Conditioning Co., New York, N. Y.—Deaerator Heater
Hamilton, J. L., Engr. Co., Charlotte, N. C.—Kiln Lining
Hanchett Mfg. Co., Big Rapids, Mich.—Knife Grinders
Harris, R. L., Inc., Knoxville, Tenn.—Pulpwood Rake
Howe Scale Co., Rutland, Vt.—Truck Scale
Hydraulic Machinery Co., Ltd., Montreal, Canada—Stock Proportioners
Hydro Silica Corp., Gasport, N. Y.—Hydro Oil Pressure Cleaner
Improved Machinery, Inc., Nashua, N. H.—Brown Stock Washers and Preknotter, Valveless Vacuum Thickeners, Bleachery Equipment and Washers, Feltless Wet Machine, Groundwood Deckers, Savealls, Vibratory Screens, Agitators
Ingersoll-Rand Co., Birmingham, Ala.—Pumps, Air Compressors
Jefferson Foundry Co., Birmingham, Ala.—Cable Conveyor Equipment
Jeffrey Mfg. Co., Columbus, Ohio—Hammer Mill, Rotary Chip Feeders
Jones, E. D., & Sons Co., Pittsfield, Mass.—Jordans, Broke Machinery Disintegrators
Keystone Engineering Co., Inc., River Rouge, Mich.—Core Cutter
Lamb-Grays Harbor Co., Hoquiam, Wash.—Pulp Cutter, Layboy and Conveyors
Lamson Corp., Syracuse, N. Y.—Paper Roll Conveyors
Laurel Machine and Foundry Co., Laurel, Miss.—Extractor Plates and Frames, Miscellaneous Tank and Boxes
Link-Belt Co., Atlanta, Ga.—Traveling Screens, Belt Tripper, Log Feeders, Turntable Machinery, Screw Conveyor, Log Stackers, Cable Conveyor Machinery, Soap Skimmer, Limestone Handling System, Gantry Cranes
Lumus Co., New York, N. Y.—Closed Feedwater Heater
Manning, Maxwell & Moore, Inc., Muskegon, Mich.—Overhead Cranes and Paper Reel Cranes
May, Stephen C., Atlanta, Ga.—Suction Heaters
Merrick Scale Mfg. Co., Passaic, N. J.—Weightometer
Midwest-Fulton Machine Co., Dayton, Ohio—Vapor Circulating Systems
Miller Hofft, Inc., Richmond, Va.—Bark Feeder
Milton Roy Co., Philadelphia, Pa.—Boiler Chemical Feed System, Pumps
Mixing Equipment Co., Inc., Rochester, N. Y.—Mixers
Montague Machine Co., Turner Falls, Mass.—Grinders and Aux.
Murray, D. J., Mfg. Co., Wausau, Wis.—Digester Stock Samplers
Nash Engineering Co., South Norwalk, Conn.—Vacuum Pump
National Conveyor & Supply Co., Chicago, Ill.—Car Shaker
Noland Co., Chattanooga, Tenn.—Quaker Conveyor Belting
North Brothers, Knoxville, Tenn.—Equipment and Piping Insulation
Norton Co., Worcester, Mass.—Pulp Stones
Oliver United Filters, Inc., New York, N. Y.—Slurry Pumps
Omega Machine Co., Providence, R. I.—Continuous Bleach Lime Slaker
Orville Simpson Co., Cincinnati, Ohio—Chip Screens
Patterson-Kelley Co., Inc., East Stroudsburg, Pa.—Hot Water Heater
Pittsburgh Lectrodryer Corp., Pittsburgh, Pa.—Air Drier
Postell, J. A., Atlanta, Ga.—Hydraulic Equipment
Purser & London, Inc., Charlotte, N. C.—Heat Exchanger
Reliance Electric & Engineering Co., Cleveland, Ohio—Pulp Drier Drive
Robbins & Myers, Inc., Springfield, Ohio—Crane and Hoist
Roberts Filter Mfg. Co., Darby, Pa.—Water Treatment Plant Equipment
Ross, J. O., Engineering Corp., New York, N. Y.—Pulp Drier, Washer and Machine Hoods, Heating and Ventilating Systems
Sarco Co., Inc., New York, N. Y.—Strainers
Savage, W. J., Co., Knoxville, Tenn.—Butting Saw and Conveyor
Simplex Wire & Cable Co., Cambridge, Mass.—Conductors
Sonoco Products Co., Hartsville, S. C.—Core Making Machinery
Southern Corp., Charleston, S. C.—Owen Pulpwood Grapple & Chip Bucket



The roll wrapping machine prepares a roll of newsprint for shipment. This machine will wrap the entire production of the two newsprint machines. This is the first type of this equipment installed in a U.S. mill

Southern Elevator Co., Greensboro, N. C.—Building Elevators
Sprout-Waldron & Co., Muncy, Pa.—Refiners
S & S Machinery Co., Brooklyn, N. Y.—Machine Tools
Stebbins Engineering & Mfg. Co., Watertown, N. Y.—Tile Chests and Lining
Toledo Scale Co., Toledo, Ohio—Scales
Torrey Roller Bushing Works, Bath, Me.—Observation Manholes
Transall, Inc., Birmingham, Ala.—Belt Conveyor Machinery
Traylor Engineering Co., Allentown, Pa.—Lime Kiln and Auxiliaries
Trimbey Machine Works, Glens Falls, N. Y.—Metering Stuff Boxes
Viking Pump Co., Cedar Falls, Iowa—Rotary Pumping Units
Warren Steam Pump Co., Warren, Mass.—Pumps
Washington Iron Works, Seattle, Wash.—Pulp Baling Press
Waterville Iron Works, Waterville, Me.—Chip Crusher
Wellman Engineering Co., Cleveland, Ohio—Pulpwood Grapple
Western Precipitation Corp., Los Angeles, Calif.—Cottrell Precipitators
Westinghouse Electric Corp., Chattanooga, Tenn.—Welding Machines, Motors, Surface Condenser, Transformers, Control Centers, Water Coolers
Whitlock Manufacturing Co., Hartford, Conn.—Chlorine Vaporizers
Williams Patent Crusher & Pulverizer, St. Louis, Mo.—Bark Shredder
Williams & Wilson, Ltd., Montreal, Canada—Paper Roll Handling Equipment Roll Wrapping Machine
Worthington Corp., Atlanta, Ga.—Pumps
Yarnall-Waring Co., Atlanta, Ga.—Digester Blow Valves

Principal Contractors for Mill Construction, Bowaters Southern Paper Corp.

Fraser Brace & Roane-Anderson, New York, N. Y.—General Contractor

Subcontractors:

Alabama Cement Tile Co., Birmingham, Ala.—Precast Roof Slabs
Alabama Painting & Roofing Co., Fairfield, Ala.—Painting Structural Steel
Asbestos Erectors, Inc., Bound Brook, N. J.—Asbestos Roofing and Siding

Automatic Heating & Equip. Co., Knoxville, Tenn.—Ventilating and Heating Filtration Plant
Bailes-Sey Contractors, Inc., Jacksonville, Fla.—Railroad Sidings (installation)
Balton & Cummings, Inc., Nashville, Tenn.—House Mark and Letters
Bethlehem Steel Co., Bethlehem, Pa.—Structural Steel
Brice Building Co., Birmingham, Ala.—Facilities Building
Caldwell & Posey, Charleston, Tenn.—Haul for Backfill
Cooney Brothers Co., Tarrytown, N. Y.—Concrete
Ceco Steel Products Corp., Birmingham, Ala.—Reinforcing Steel
Chattanooga Steel Erectors, Chattanooga, Tenn.—Placing Reinforcing
Currin Co., Chattanooga, Tenn.—Fire Doors
Cyclone Fence, Div. of American Steel & Wire, Charlotte, N. C.—Fencing
Eichleay Corp., Pittsburgh 3, Pa.—Erecting Equipment; Driving Sheet Piling
Elevator Service Co., Knoxville, Tenn.—Erecting Freight Elevators Furnished by Southern Elevator Co.
Emmett, Tom, Knoxville, Tenn.—Cement Finishing
Fischbach & Moore, Inc., Atlanta, Ga.—Electrical Installation
Grinnell Co., Inc., Atlanta, Ga.—Process Piping
Grinnell Co., Inc., Chattanooga, Tenn.—Underground Sprinkler Piping; Sprinkler System, Mulsifyre System for Protection of Transformers & Circuit Breakers at Grinder Substation
Gunite Construction Corp., New York, N. Y.—Lining Log Pond
Hailey, W. L., & Co., Inc., Nashville, Tenn.—Pumping Station and Filtration Plant Electrical Work—Filtration Plant
Hale & Wallace, Inc., Chattanooga, Tenn.—Toilet Partitions and Tile Floors
Hauserman, E. F., Co., Cleveland, Ohio—Office Partitions
Herb Hairell Drilling Co., Athens, Tenn.—Well Drilling
Knobloch & Co., Houston, Tex.—Finished Painting of Equipment and Building Items
Marshall, Jake, Chattanooga, Tenn.—Sanitary Plumbing
Miller, J. L., Chattanooga, Tenn.—Lath and Plaster Works
Oman Construction Co., Nashville, Tenn.—Water Lines and Sewers; Grading; Raw Water Supply Main
Parks, T. U., Chattanooga, Tenn.—Foundation for Butler Buildings
Pennsylvania Wire Glass Co., Philadelphia, Pa.—Corrugated Glass Panels
Penuel, A. G., Jr., Atlanta, Ga.—Butler Buildings
Raymond Concrete Pile Co., New York, N. Y.—Piles and Driving
Southern Blow Pipe & Roofing Co., Chattanooga, Tenn.—Air Conditioning and Heating
Southern Fireproofing Co., Cincinnati, Ohio—Brick and Tile
Southern Railway System, Knoxville, Tenn.—Railroad Siding (Materials)
Standard Iron & Wire Works, Chattanooga, Tenn.—Machine Guards
Tri-State Roofing Co., Knoxville, Tenn.—Roofing and Waterproofing

Scott

George N. Carleton has been elected a director and a vice-president of Scott Paper Co. In 1944 Mr. Carleton became a director and president of Detroit Sulphite Pulp & Paper Co., all of the assets of which were acquired by Scott on September 2, and which will be operated as a division of Scott with Mr. Carleton as principal operating executive.

G. N. Carleton, Scott Paper Co.

S. D. Warren

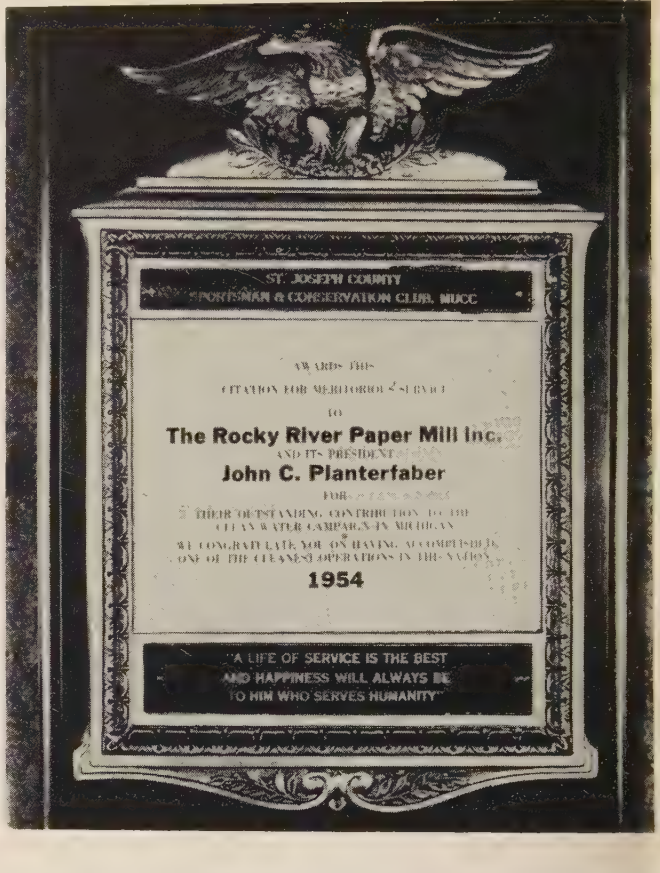
S. D. Warren Co., Cumberland Mills, Me., is using a nuclear gage to trigger an electronic system for controlling pulp flow to the paper machine. The average basis weight of the sheet is read continuously by a scanning nuclear gage. When this average varies from specified tolerances, the gage signals the controller, which raises or lowers the stuff gate accordingly. Manufactured by Industrial Nucleonics Corp., Columbus, Ohio, the system is said to have reduced basis weight variance appreciably.

Downing

Phil Bowen has been appointed plant manager of Downing Box Co., Milwaukee, Wis.

Rocky River

Rocky River Paper Mill, Inc., Three Rivers, Mich., has been awarded a plaque by the St. Joseph County Sportsman


ST. JOSEPH COUNTY
SPORTSMAN & CONSERVATION CLUB, MICC
AWARDS THIS
CITATION FOR MERITORIOUS SERVICE
TO
The Rocky River Paper Mill Inc.
AND ITS PRESIDENT
John C. Planterfaber
FOR
THEIR OUTSTANDING CONTRIBUTION TO THE
CLEAN WATER CAMPAIGN IN MICHIGAN
WE CONGRATULATE YOU ON HAVING ACCOMPLISHED
ONE OF THE CLEANEST OPERATIONS IN THE NATION
1954
"A LIFE OF SERVICE IS THE BEST
AND HAPPINESS WILL ALWAYS BE
TO HIM WHO SERVES HUMANITY"

& Conservation Club for its outstanding contribution to the clean water campaign in Michigan.

St. Regis

The Pulp Division of St. Regis Sales Corp., subsidiary of St. Regis Paper Co., opened an office at 1720 Section Rd., Cincinnati, Ohio, on September 15. William M. McNair is in charge of the new office.

North Western Pulp and Power, Ltd. recently elected a new slate of officers as a further step in connection with the financing and construction of a 300-ton bleached kraft mill at Edson, Alberta. North Western is jointly owned by St. Regis and North Canadian Oils, Ltd.

St. Regis has awarded five undergraduate forestry scholarships for 1954–55, as part of its scholarship program. Three of the awards are made in the South, and one each in the Northwest and Northeast.

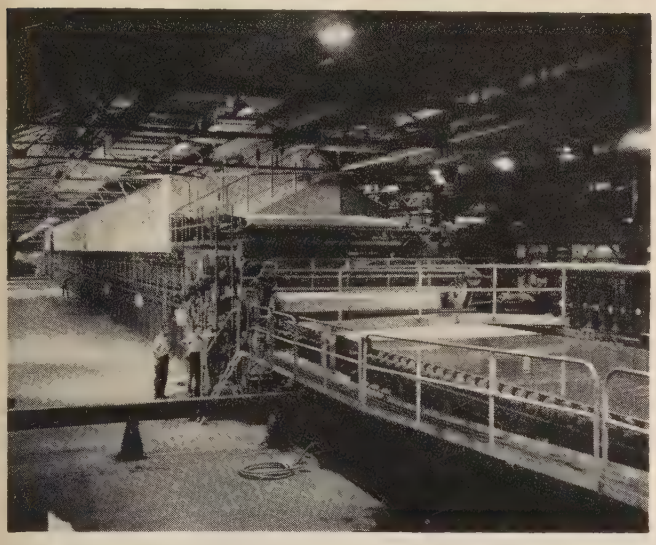
Falls Paper & Power

More than 7,000,000 gallons of spent liquor from the sulphite mill of the Falls Paper & Power Co., Oconto Falls, Wis., has been used this year as road binder by August 25. With continuing good weather for road work it was expected that

the total might reach 9,000,000 gallons, three times the quantity used in 1953.

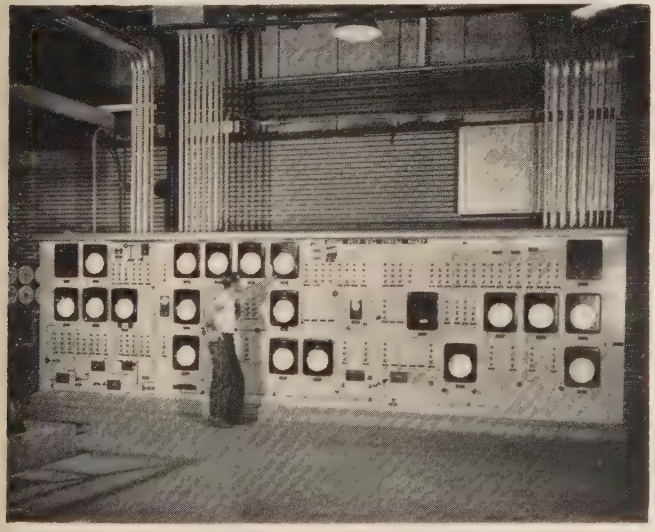
Alton

Alton Box Board Co., Alton, Ill., has developed a new corrugating medium known as Cor-U-Cel, that gives straw fiber new importance as a paperboard raw material.



This fourdrinier paperboard machine, longer than a football field, was installed by Alton Box Board Co., Alton, Ill., for the manufacture of Cor-U-Cel

Having determined that the crush resistance of corrugated medium is related to pentosan content Alton chemists developed a new process to produce pulp from wheat straw without losing the pentosans present in the straw. After proving the process on a pilot plant scale, Alton rebuilt its straw processing, pulping, and refining equipment and its no. 3 machine. The new machine is a Beloit fourdrinier.



From one panel, technicians control the precise processing, pulping, washing and refining of wheat straw used in the manufacture of Cor-U-Cel, a new type of paperboard developed by Alton Box Board Co., Alton, Ill.

Cor-U-Cel is said to be superior in crush resistance and runability to all other media.

Southland

Southland Paper Mills, Inc., Lufkin, Tex., has awarded a contract for the construction of their new no. 3 newsprint machine to The Pusey and Jones Corp., Wilmington, Del. Delivery is scheduled for early 1956. The machine will be the latest high-speed design and construction, wire width 210 in., equipped with vacuum pick-up attachment and for a maximum speed of 2000 f.p.m. This will be the second Pusey-Jones machine to be installed in the Lufkin mill. Their no. 1 machine was installed January 1940, when the mill went into operation.

Crown Zellerbach

Robert T. Kimberlin has been elected vice-president of Crown Zellerbach Corp. and Donald R. Schmidt, formerly assistant secretary, was elected secretary to succeed Kimberlin. In his new position Mr. Kimberlin will be responsible for organization planning and the development of administrative procedures. He joined the company as assistant to the president in 1938, and was named secretary in 1951.

Rayonier

Rayonier Inc. is a 27-year-old chemical cellulose producer accounting for approximately 50% of total United States chemical cellulose capacity, 32% of North American capacity, and 20% of the world's.

With the new Jesup, Ga., mill, Rayonier now operates five chemical cellulose plants. Three are in the state of Washington at Hoquiam, Shelton, and Port Angeles, while another is located at Fernandina Beach, Fla.

The company owns or controls some 845,300 acres of woodlands in the Northwest and Southeast, an area, incidentally, larger than Rhode Island. Of these extensive timber reserves, 462,550 acres are in Georgia and Florida. A forestry division scientifically manages these timber stands, assuring continued growth and an economic source of cellulose. This demonstrates the easy replenishability of this vital raw material.

Rayonier operates a sizable transportation and communication system comprising 625 miles of truck roads; a railroad system including 225 miles of track, 20 locomotives (from 45-ton to 131-ton Baldwins), 28 speeders, maintenance yards, and roundhouses; eight radio transmitting bases; 80 mobile units; a series of tidewater docks at all plants except Jesup.

Rayonier employment is nearly 4000. For 1953 the company sold 404,205 tons of cellulose products, consuming 434,923,000 board feet of pulpwood.

Glatfelter

P. H. Glatfelter Co., Spring Grove, Pa., experimented last Summer with "weather modification" in an attempt to combat drought conditions which threatened the mill water supply. W. E. Howell Associates were engaged to carry out silver iodide cloud seeding from the ground and by airplane. The experiment was found successful during one 11-day period when Spring Grove had 2.33 in. of rain while surrounding areas had less than 2 in.

Brown—I.P.

Agreement was reached recently for the sale by Brown Corp. of its Quebec woodland holdings and bleached kraft mill to Canadian International Paper Co., and of its power interests to Shawinigan Water and Power Co. The properties to be sold to C.I.P. include approximately 2,500,000 acres of woodlands and the pulp mill at La Tuque, Que., which has an annual capacity of about 165,000 tons of high-grade bleached kraft.

Charmin

Charmin Paper Mills, Green Bay, Wis., expects to start up its yeast plant before the end of 1954. Yeast from the plant will be marketed by Red Star Yeast and Products Co., Milwaukee, Wis. Total cost of the project is estimated at $2,865,000.

K-C

Kimberly-Clark Corp., Madison, Wis., expects to cut its bark loss to the river by 70% this Winter, and spent liquor outflow will be controlled to maintain a satisfactory dissolved oxygen level in the Menominee River. In critical periods the mill will practice ponding, irrigation, or possibly even temporary curtailment of production.

Olin Mathieson

The following officers of Olin Mathieson Chemical Corp., formed August 31 by the merger of Olin Industries, Inc., and Mathieson Chemical Corp., were elected recently:

John W. Hanes, chairman of the Finance Committee and vice-president for finance; F. Stillman Elfred, John C. Leppart, Stanley de J. Osborne, executive vice-presidents. Russell R. Casteel, vice-president; Norman H. Collisson, vice-president for operations; Donald W. Drummond, vice-president for operations; R. L. Hockley, vice-president for operations; Russell Hopkinson, vice-president for development; Robert W. Lea, vice-president for organization; R. B. Lewis, vice-president for financial analysis; David T. Marvel, vice-president for sales; Milton F. Meissner, vice-president for operations; S. L. Nevins, vice-president for operations; Walter F. O'Connell, vice-president and assistant to the vice-president for finance; Fred Olsen, vice-president for research; Ralph A. Ostberg, vice-president for production; J. J. Toohy, vice-president for operations; Theodore Weicker, Jr., vice-president for overseas operations; Edgar W. Taft, treasurer; C. C. Tallman, comptroller; Gordon Grand, Jr., secretary; E. R. Van Vliet, assistant treasurer; A. P. Winsor, assistant secretary.

Olin is the name selected for the site of the new cellophane plant to be constructed in Indiana by Olin Mathieson.

Synthane

Synthane Corp., Oaks, Pa., has chalked up 25 million man-hours with an average accident frequency rate of 5.39. The chief hazard in the company's laminated plastics plant is the flammable nature of the resins, solvents, paper and cloth used in the process.

A Kidde automatic system is used for fire protection. If a fire occurs in one of the impregnating machines, CO_2 is immediately directed from 10 discharge nozzles at the surface of the bath, completely enveloping and smothering the flames. At the same time, an automatic explosion-proof switch shuts down all electrical machinery. In addition, a two-source water sprinkler system covers the entire plant.

Tribune

The *Baie Comeau*, newest member of the Chicago *Tribune's* paper fleet, was completed recently in Wales, and is now in service, carrying newsprint from Canadian mills to the *Tribune* and the New York News. Tenth member of the *Tribune* fleet, the vessel is 259 ft. long with a deadweight of 3010 tons, a draft of 14 ft. in fresh water, and a loaded speed of $10^1/_2$ knots.

Union Bag

The ticklish job of straightening a bent metal shaft, 8 ft. long and 11 in. in diameter, which drives a 10-ton chipper disk was recently carried out by the maintenance department of Union Bag & Paper Corp., Savannah, Ga., at a saving of around $20,000.

The shaft was on the no. 3 chipper in the woodroom, and an operating accident had thrown it out of line a little over 82 thousandths of an inch.

While such a small bend might not seem important to the average person, when the big 700-hp. motor hooked to the shaft started turning it at the prescribed 300 r.p.m., it became obvious that the equipment could not function properly, for even a misalignment that slight caused the 110-in. disk to run out approximately two thirds of an inch. And such heavy equipment must work to very close tolerances.

A new shaft and labor cost to put the chipper back in good operating condition was estimated at $20,000. This high cost plus some typical UB thinking resulted in a trial at reclaiming the shaft with a process known as "flame straightening."

Here's how the process works. The shaft was checked very closely using dial indicators to determine the highest point of the bend. A small spot about 2 in. in diameter was heated to a temperature of about 1325° at the high point. This spot was allowed to cool slowly and the shaft was again checked. The resulting contraction removed 0.0155 in. of the bend from the shaft. It was necessary to repeat the heating, cooling, and checking cycle fifteen times.

Western Michigan

The following scholarships have been awarded to students in the Paper Technology Dept. at Western Michigan College, Kalamazoo, Mich.

Black-Clawson Co. Scholarship, Donald Harbron, Jr.; H. P. Broyfoglo Scholarship, Philip R. Carey; Norman Bardeen Scholarship, William A. Foster; Paper and Twine Association Senior Scholarship, Leonard Timmer; Paper and Twine Association

Top row, left to right: W. L. Abshire, Jr., L. R. Bortolotti, P. R. Carey, W. A. Foster, and Thomas Murwin. Middle row: Donald Harbron, Jr., G. W. Lawton, Jr., J. A. Lewis, and Terry Lovett. Bottom row: Orrin Parmelee, Donald Pryor, Richard Tough, Leonard Timmer, and Terry Tiffany

Sophomore Scholarship, Thomas Murwin; Paper and Twine Association Sophomore Scholarship, Donald Pryor; Science and Paper Technology Scholarships, George W. Lawton, Jr.; Moore and Munger Scholarship, Orrin Parmelee; William Slavin-Hawthorne Paper Co. Scholarship, Richard Teugh; Charles E. Nolson Scholarship, Terry Lovett; Fred C. Boyce Award of the Michigan division, American Pulp and Paper Mill Superintendents' Association, James A. Lewis; Paper and Twine Association Salesmanship Award, William L. Abshire, Jr.; Paper and Twine Association Sophomore Award, Terry Tiffany; Kalamazoo Valley Section, TAPPI, Senior Student Award, Lawrence R. Bortolotti.

Syracuse

National Starch Products Co., Plainfield, N. J., has awarded continuance of a $2500 fellowship to State University of New York College of Forestry. The fellowship was accepted by William J. Andrews for studies on resin additions to paper and various beater addition problems.

U. of Maine

The Brown Co., Berlin, N. H., has taken a company membership in the University of Maine Pulp and Paper Foundation.

Stefan A. Zieminski of Zaleszczyki, Poland, has been appointed associate professor of chemical engineering at the University.

N. C. State College

The Gardner Board and Carton Co., Middletown, Ohio, has made a $1000 contribution to the pulp and paper training and research program in the school of forestry at North Carolina State College, Raleigh, N. C.

Robert Grant Hitchings has been appointed assistant professor of pulp and paper technology in the school.

Maintenance Show

The next Plant Maintenance and Engineering Show will be held at the International Amphitheatre, Chicago, Ill., Jan. 24–27, 1955.

Gurley

W. & L. E. Gurley, Troy, N. Y., has issued a bulletin (no. 1400) describing Gurley testing instruments and procedures for using them.

Geigy

The following appointments have been made by the Paper Dept., Geigy Dyestuffs Division, Geigy Chemical Corp: John J. De Jongh, Groton, Mass., will continue to call on New England accounts and will also cover parts of New York State; F. G. Thwaites, Toronto, Ont., will continue to service the mills in the Ontario area and also in the West; D. J. Nixon, New York, N. Y., will cover paper mills in the Philadelphia area and will also continue to cover accounts in the New York area and act as technical aid and sales consultant to L. C. Voss in the Ohio area; H. H. Gottsleben, Appleton, Wis., will continue to call on accounts in Wisconsin, Minnesota, and Michigan, and will be assisted by William A. Ludke; Daniel P. Fessia, New York, N. Y., will act as technical aid and sales consultant for Charlotte, N. C., and Chicago, Ill., branches; and Walter Kenowski will head laboratory service in New York.

Clark-Aiken

Clark-Aiken Co., Lee, Mass., has issued a bulletin describing the new Clark-Aiken Stub Shaft Assembly.

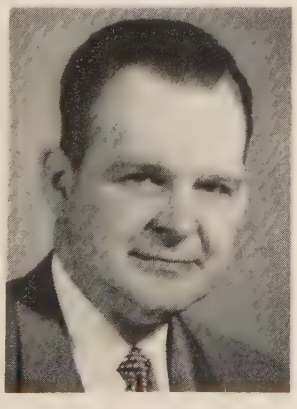
Downingtown

W. Malcolm Orchard has joined Downingtown Mfg. Co. as a sales engineer specializing in stock preparation systems and equipment.

Staley

Lester D. Borden has been appointed manager of the Philadelphia office of A. E. Staley Mfg. Co., Decatur, Ill. Natt K. Hammer has been appointed assistant manager of Staley's industrial sales department.

W. M. Orchard, Downingtown Mfg. Co.



N. K. Hammer, A. E. Staley Mfg. Co.

Dorrco

The Dorr Co., Stamford, Conn., has redesigned the green liquor clarifier in the Dorr Continuous Recausticizing System, based on the principle of selective density feeding.

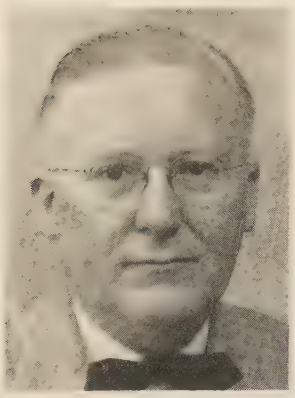
Left to right: J. D. Hitch, Jr., president; J. V. N. Dorr, founder and chairman of the Dorr Co.; and E. R. Ramsey, vice-chairman and ex-president, at the presentation of a model Classifier to Dr. Dorr on the occasion of the 50th Anniversary of its invention

On Aug. 23, 1954, John V. N. Dorr, founder and chairman of Dorrco, was presented by 100 members of his veteran staff with a scale model of the first Dorr Classifier in celebration of the 50th anniversary of its inception.

An exact scale model of the first Dorr Classifier

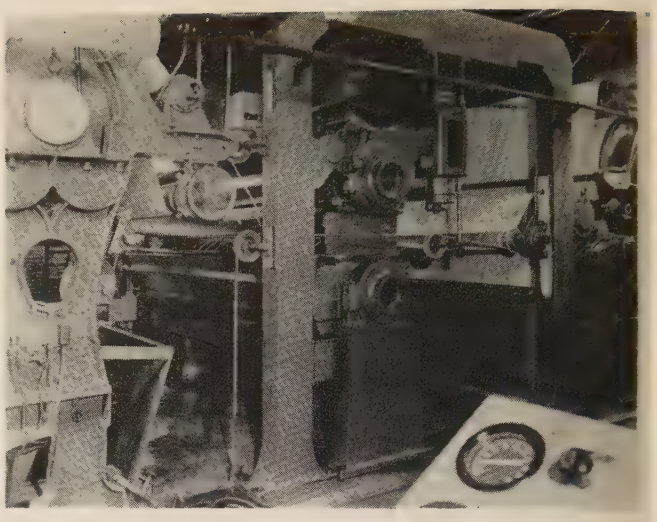
Antara

Joseph P. Madden has joined Antara Chemicals, a sales division of General Aniline & Film Corp., as manager of inorganic chemicals.



J. P. Madden, Antara Chemicals

E. M. Root, Black-Clawson (Canada) Ltd.

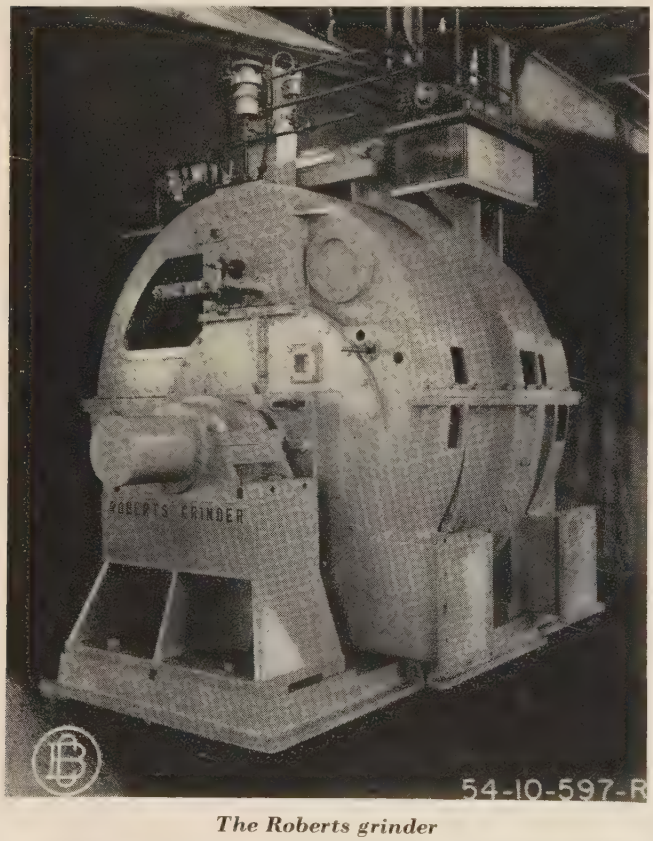


B-C size press

BLACK-CLAWSON

Upon acquisition of the Bagley & Sewall Co., Watertown, N. Y., The Black-Clawson Co. has entered into an agreement with the F. W. Roberts Mfg. Co., Inc., Lockport, N. Y., for manufacture and sale of the patented continuous Roberts Grinder under the Shartle Bros. Division.

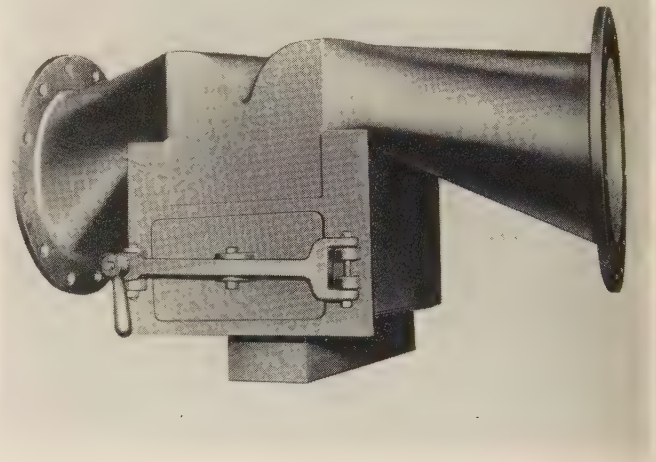
Black-Clawson's Shartle Bros. Division has introduced the Alligator, a new type of stock refiner claimed to give outstanding performance, particularly with respect to fiber control and power economy.



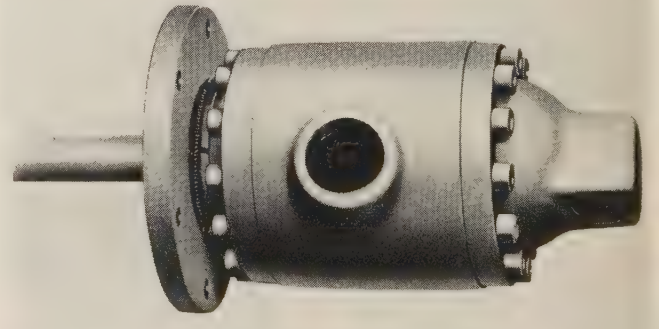
The Roberts grinder

The sales and manufacturing agreement between Black-Clawson and Alexander Fleck Ltd., Ottawa, Ont., was terminated on September 30. Black-Clawson has formed a Canadian subsidiary, Black-Clawson (Canada) Ltd., with offices in the Dominion Square Bldg., Montreal, Que. Cliff R. Crawford is president of the subsidiary and Edward M. Root is vice-president and general manager.

Black-Clawson is manufacturing three new products: a new size press using two rotochambers, one for loading and one for lifting; a new magnetic separator for installation in the line ahead of refiners, jordans, pumps, screens, or paper machines; a new spiro-flow steam joint, featuring a tangential spiral steam inlet for driers.



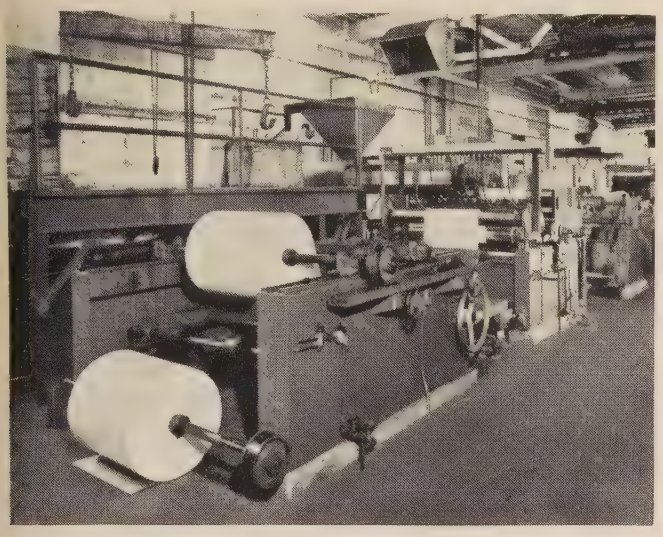
Black-Clawson magnetic separator



Black-Clawson Co. Spiro-flo steam joint

EGAN

Frank W. Egan & Co., Bound Brook, N. J., recently supplied a polyethylene extrusion laminator to Riegel Paper



The Egan polyethylene extrusion laminator at the Riegel Paper Corp. mill at Milford, N. J.

Corp., Milford, N. J. The new machine produces polyethylene coated glassine papers with coating thicknesses of 0.0005 to 0.0015 in. and higher at speeds of 45 to 400 f.p.m. in widths up to 42 in.

EBASCO

Ebasco Services, Inc. has opened an office in Portland, Ore., under William F. Rooney.

DIAMOND ALKALI

Kemble S. Lewis has been appointed sales manager of the Plastics Division of Diamond Alkali Co., Cleveland 14, Ohio. Olin Smith replaces Mr. Lewis as assistant branch manager in Chicago.

HONEYWELL

Minneapolis-Honeywell Regulator Co., Minneapolis, Minn., has purchased the assets of Heiland Research Corp., Denver, Colo.

LANGSTON

Samuel M. Langston Co., Camden, N. J., has completed a $250,000 addition to its Camden plant, to house the company's offices and provide additional erection space for Langston printer-slotters.

JOHNS-MANVILLE

Johns-Manville Corp. opened the largest asbestos mill in the world at Asbestos, Que., on Sept. 30, 1954. It will mill more than one third of the free world's supply of asbestos fiber, most of which finds it way to the United States to be manufactured into scores of essential products for home, farm, industry, and national defense. The new mill will replace several existing mills and provide more modern facilities with increased production capacity at lower operating costs. It is the latest project of the Quebec asbestos mining industry, which has embarked upon a $70,000,000 program of expansion and development of new mines, mills, and machinery.

The new mill occupies a 14-story, steel and concrete building that has $22^1/_2$ acres of floor space. When in full production early in 1956 it will provide additional capacity to reach a total annual production of 625,000 tons of asbestos fiber, and a daily capacity of 60 carloads aggregating 2500 tons. Adjacent to the famous J-M Jeffrey Mine, long known as the largest asbestos mine in the world, the new mill will draw on ore reserves for more than 100 years of operation at the present rate of production.

Aerial view of new mill at Canadian Johns-Manville Jeffrey Mine, Asbestos, Que., now half completed, also shows in the background the town of Asbestos, and other mining and milling facilities. At left foreground, is the dry rock storage building with a capacity of 60,000 tons of ore; beyond are some of the old milling facilities which the new mill will replace. In middle center is the headframe above one of the two underground mine shafts now in operation at the Jeffrey Mine

Equipped with the most modern lighting, safety devices, and dust control equipment, the new mill is expected to provide the safest and healthiest working conditions of any fiber mill in Canada or the United States.

There are 4000 separate dust enclosures, utilizing 4 miles of piping and 12 miles of control wiring in the dust control system. It takes 30 acres of cloth to provide bags used in filtering dust as the ore is milled. When in full operation, the new mill will have air handling equipment capable of purifying 2,500,000 cu. ft. of air each minute. There are 5000 separate

Open pit mine and plant are shown above. The open pit mine now accounts for only about 28% of the total asbestos fiber production at the mine, since most ore is now produced by underground operations located beneath the pit. The plant, in foreground, is the largest in Canada devoted to the production of asbestos building and industrial products and allied materials

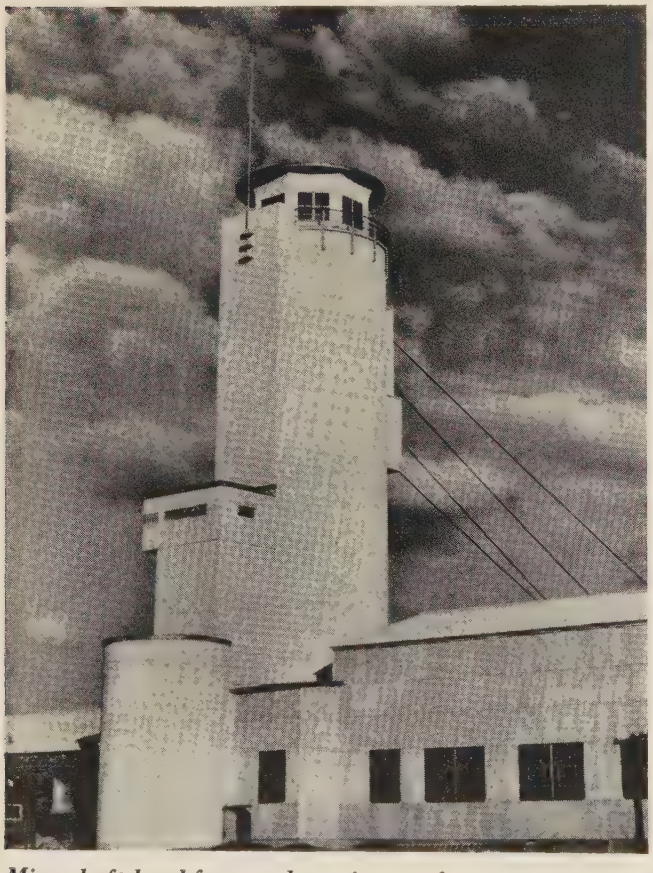
safety guards on the milling equipment and more than 4600 fluorescent lighting units.

In 1953 production of asbestos fiber in Canada amounted to 911,713 tons at a value of $87,633,124. This was 65% of the free world's asbestos production. Of this output, 97% was exported, mainly to the United States. The United States, which consumes some 70% of the free world's production, gets 70% of its supply from Canada. Johns-Manville, alone, produces more than half of the asbestos fiber mined in Canada, providing jobs for more than 2600 men and women at the Asbestos, Quebec, mine, mill and plant operation with an annual payroll in excess of $10,000,000. The company operates a second asbestos mine and mill near Matheson, Ontario. This is known as the Munro Mine, which produces about 25,000 tons of asbestos fiber annually.

The new mill at Asbestos is constructed of steel and concrete. It is a 14-story building covered with "Transite" sheathing—an asbestos-cement product manufactured by Johns-Manville. The first half of the building is now completed and 25% of the machinery is installed and ready to go into operation. The entire project should be completed by the Spring of 1956. This new plant incorporates the most modern facilities for the milling and production of high quality asbestos fibers—an essential objective in today's competitive asbestos industry.

Pertinent construction and operating statistics include:

1. Dimensions of building: length 432 ft.; width 330 ft.; height 195 ft.
2. Earth excavated for site clearing—300,000 cu. yd.
3. Tons of structural steel—7700 tons plus 2000 tons in chutes and air lines.
4. Yards of concrete—30,000 cu. yd.
5. "Transite" sheathing—938,000 sq. ft.
6. Floor area (14 floors)—972,000 sq. ft. or 22½ acres.
7. Rubber belting—5.2 miles.
8. Electric conduit—30 miles.
9. Fiber aspiration piping—7 miles.
10. Rock and fiber chutes—10 miles.
11. Dust control piping—4 miles plus 4000 dust enclosures.
12. Area of cloth bags in dust filter—30 acres.
13. Control wiring on dust system—12 miles.
14. Fluorescent lighting—4600 units.
15. Safety guards on equipment—5000.
16. Connected horsepower—15,000 hp.
17. Air consumption—2,500,000 cu. ft. air/min.
18. Total number of employees (in 1956)—600.
19. Yearly production capacity—625,000 tons of fiber.
20. Capacity in carloads of fiber shipped per day—60 or 2500 tons.



Mine shaft head frame, above, is one of two underground mine shafts which now produce about 72% of Jeffrey Mine's total asbestos ore production. The method used underground is known as block-cave mining. In this method a shaft is sunk outside the main orebody to a depth of 1000 ft. From this shaft horizontal tunnels are cut into the ore body. This is then undercut in blocks 200 by 200 ft. square. The blocks are as high as a 40-story building. Underground at the Jeffrey Mine are approximately 30 miles of tunnels from which ore is removed by rail to primary crushers more than 800 ft. underground. From that point it is hoisted to the surface for milling

In brief, the new mill makes possible more efficient ore treatment resulting in the production of cleaner fibers, more acceptable for certain uses in Johns-Manville plants and consistent with the latest customer specifications. Embodying greatly improved working conditions, it will continue to provide a safe and healthy place to work.

F & P

The August, 1954, issue of *Ratonews*, published by Fischer & Porter Co., Hatboro, Pa., contains a description of the instrumentation used with the automatic split-stream Zeolite water treatment system at the Hellgate station of Consolidated Edison Co. in New York.

F & P has issued the following pulp and paper industry application bulletins: Flow Measurement and Control in Pulp and Paper Mills (90-130-17), Kraft Digester Controls (90-130-18), Instrumentation of Black Liquor Evaporators (90-130-19).

Hercules

William W. Delaney has been appointed manager, eastern division, Joseph M. Carbonera, manager, western hemisphere division, and Curtis M. Hinsley, supervisor, European division, of the Export Dept. of Hercules Powder Co., Wilmington, Del.

Hercules has issued a technical booklet about the use of Dresinate as an emulsifier, detergent, and dispersant in soluble oils and cleaning compounds, and a technical booklet describing all the products commercially available from its synthetics department.

Jones-Fleck

E. D. Jones & Sons, Pittsfield, Mass., and Alexander Fleck Ltd., Ottawa, Ont., have made a two-way manufacturing and sales agreement under which Fleck will manufacture and sell Jones equipment in Canada and Jones will manufacture and sell the Fleck line in the United States.

Cleaver-Brooks

Cleaver-Brooks Co., Milwaukee, Wis., has completed arrangements for the manufacture in Canada of its 30 and 40-hp. new CB boiler line.

Appleton Woolen Mills

F. H. Orbison has been named general manager of Appleton Woolen Mills, Appleton, Wis., succeeding A. H. Wickesberg, who becomes board chairman. Other new officers are: Ann H. Orbison, president, Elizabeth Nelson, vice-president, A. H. Thuerer, secretary, and C. P. Heeter, treasurer.

Kohler

Oliver C. Tate has been appointed executive assistant chief engineer of John B. Kohler, Ltd., Crystal Lake, Ill.

G.E.

General Electric Co., Schenectady, N. Y., supplied $3^1/_2$ million dollars worth of equipment to the new Bowaters Southern Paper Corp.'s newsprint mill at Calhoun, Tenn.

Fuller

Fuller Co., Catasauqua, Pa., has issued a bulletin (G-2) on bulk pneumatic handling of dry pulverized materials.

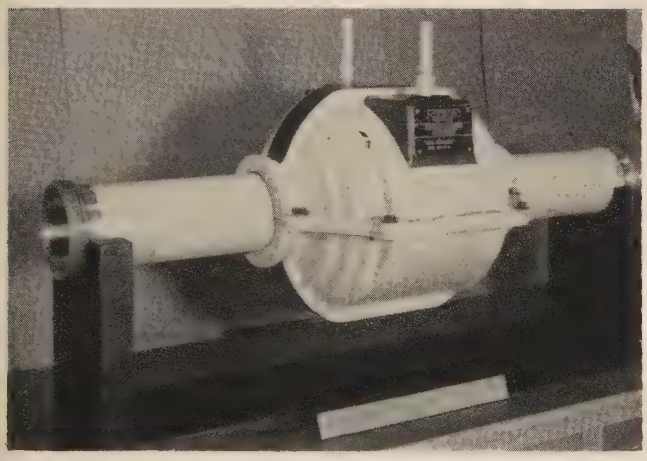
Albany

Albany Felt Co. of Canada, Ltd., has offered Canadian felt manufacturers licenses to produce synthetic-content paper machine felts as covered by a patent recently granted to the company. The Canadian patent is identical to that granted to Albany Felt Co., Albany, N. Y., in 1947, covering the use of nylon in papermakers' felts in percentages from 5 to 70.

Employees of Albany Felt Co., Albany, N. Y., were featured on the television series, Industry on Parade, during September and October, for their outstanding personal service to the community.

Foxboro

The Foxboro Co., Foxboro, Mass., has issued a technical report (TI 27-A-71a) describing its new electromagnetic flowmeter for 2 to 8-in. lines.



New Foxboro magnetic flow meter

Permutit

The Permutit Co., New York, N. Y., has issued a bulletin (No. 2225 B) describing its line of pressure filters and accessories.

Lobdell

Lobdell United Co., subsidiary of United Engineering and Foundry Co., Wilmington, Del., has issued two new bulletins, one covering the Bridgeport Line of Grinding Machinery and one describing the Bridgeport Line of "Abrasaw" Abrasive Cut-Off Machines.

Chemipulp

David M. Shapleigh has been appointed sales engineer for Chemipulp Process, Inc., Watertown, N. Y.

Research Corp.

Eight pulp and paper mills will have added Research Corp. precipitation equipment during 1954. Total cleaning capacity of the new Cottrells is 1,608,000 cu. ft. per minute. Installations are being made at St. Joe Paper Co., Port St. Joe, Fla.; Gaylord Container Corp., Bogalusa, La.; Longview Fibre Co., Longview, Wash.; National Container Corp., Valdosta, Ga.; Rome Kraft Co., Rome, Ga.; Rayonier, Inc., Doctortown, Ga.; Buckeye Cellulose Corp., Foley, Fla.; Continental Can Co., Hopewell, Va.

Raybestos-Manhattan

The Manhattan Rubber Division of Raybestos-Manhattan, Inc., Passaic, N. J., has issued a brochure (no. 6638) describing the Poly-V drive, new multiple-grooved belt and V-grooved sheave.

Allied Chemical and Dye

Allied Chemical & Dye Corp., New York, N. Y., recently dedicated its new General Chemical Division research laboratory in Morris Township, N. J. The new $2 million facility provides over 55,000 sq. ft. of floor space for research work in industrial, scientific, and agricultural chemicals, and is directed by J. H. Pearson.

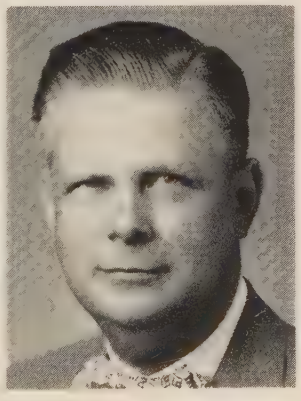
General Chemical Research Laboratory, Morris Township, N. J.

Rice Barton

W. Ernest Stone has been appointed assistant sales manager, paper machinery, and R. Donald Rusden, assistant sales manager, textile machinery, for Rice Barton Corp., Worcester, Mass.

Rhodia

Warren B. Thompson has been appointed sales representative in the middle Atlantic states for Rhodia, Inc., New York, N. Y.



W. E. Stone, Rice Barton Corp.

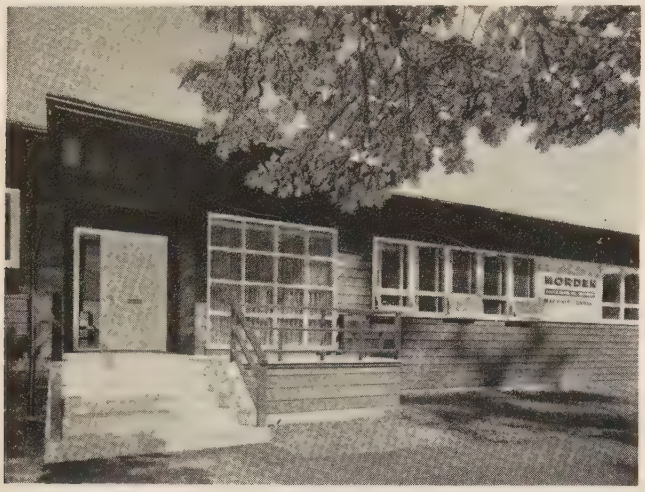
W. B. Thompson, Rhodia, Inc.

ARMSTRONG

Armstrong Machine Works, Three Rivers, Mich., has published a bulletin (No. 266) explaining the principles of the new Armstrong syphon scoop for draining cylinder driers.

MORDEN

Morden Machine Co. has moved into its own building at 3420 S. W. Macadam Ave., Portland, Ore. The new structure has facilities for all the firm's administrative, engineering, service, and sales staffs, and laboratory space for tests with the Morden Slush-Maker.



New office of the Morden Machine Co.

ROOTS BLOWERS

Roots-Connersville Blower, a division of Dresser Industries, Inc., has published a booklet in celebration of its 100th anniversary. The story of the Roots anniversary was carried in the June, 1954, issue of *Tappi*, pages 131A and 132A.

CRANE

Crane Co., Chicago, Ill., supplied approximately 250 valves, as well as other piping materials, to the Champion-International Co., Lawrence, Mass., in connection with the modernization of Champion's chemical mill, which produces calcium carbonate, sodium hydroxide, and calcium hypochlorite.

WESTINGHOUSE

A. C. Meixner has been appointed assistant sales manager of apparatus products for Westinghouse Electric Corp., Pittsburgh, Pa. H. C. McDaniel has been named Westinghouse manager of technical information.

MALLINCKRODT

Charles L. Crump has been named western division sales manager in charge of laboratory chemicals for Mallinckrodt Chemical Works, St. Louis, Mo. William W. Scott has been appointed assistant to Mr. Crump.

PATTON

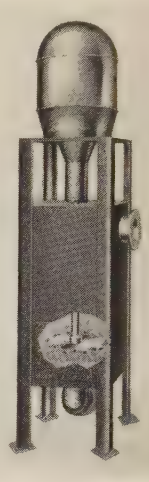
The Patton Manufacturing Co., Springfield, Ohio, machinery manufacturers specializing in the design and manufacture of paper mill and printing equipment, recently established its paper mill division as a separate element of the company's organization.

George S. Herbert, formerly of Ross Midwest Fulton Machine Co., is manager of the paper mill division, which now has full-time managerial and technical personnel and is devoting its resources to the development, manufacture, and sale of paper mill machinery, as well as to modernization and rebuilding of existing paper mill equipment. Sales manager of the division is Wayne T. Crannell, formerly of Sandy Hill Iron & Brass Works, Black-Clawson Co., and Ross Midwest Fulton Machine Co.

Patton has published a booklet describing in detail its background, facilities, personnel, and capacities.

COWLES

The Cowles Co., Cayuga, N. Y., is manufacturing a new machine, the Cowles Selective Defiberizer, which, it is claimed, defibers screen rejects with high efficiency and low maintenance.



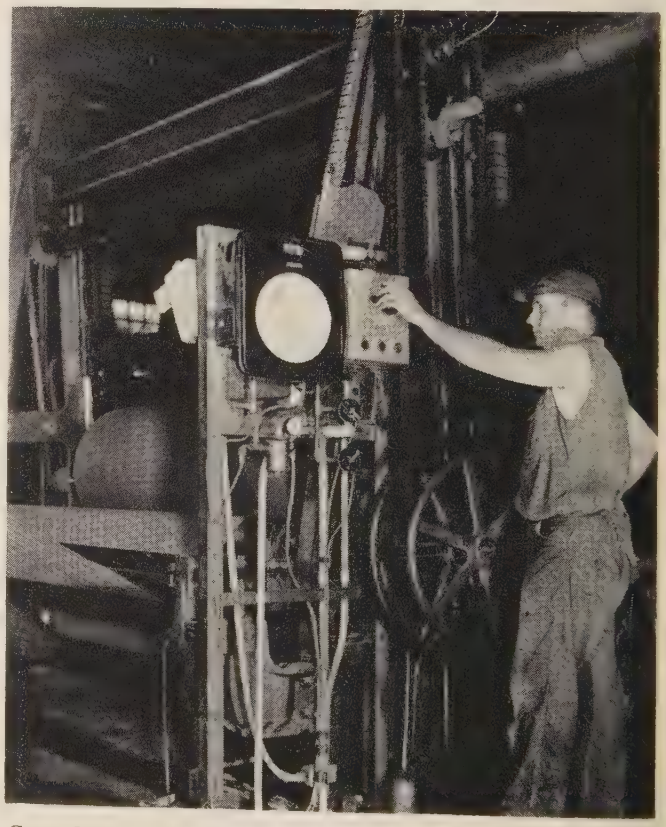
The new Cowles Selective Defiberizer

ROHM & HAAS

Rohm & Haas Co., Philadelphia, Pa., recently reduced prices by $2^1/_2$ to $3^1/_2$ cents per lb. on one of its most widely used surface-active agents, Triton x-100.

LINK

Link Engineering Co., Detroit, Mich., has developed a new tension control system, "Lod-Cap," suitable for paper rewinding operations. The unit can be installed with a one-hour shutdown and is claimed to require little maintenance.



Consolidated Paper Co. of Monroe, Mich., reports that use of the revolutionary Lod-Cap unit on Cameron rewind machines has resulted in smoothly flowing production with work stoppage due to tension variations or breaks reduced and that paper rolls turned out with the assistance of the Lod-Cap are uniformly tight and well-wound

LOCAL SECTION ACTIVITIES

Reports of Meetings, Personnel, and Events

Lake States

The first meeting of the Lake States Section of TAPPI was held in Appleton, Thursday, September 23. The meeting was held earlier than usual this Fall so that it would coincide with the symposium on the paper machine held at The Institute of Paper Chemistry. The meeting was opened to people of the symposium as well as Lake States TAPPI members. Total attendance approximated 300.

Among the guests were R. G. Macdonald, who spoke on behalf of National TAPPI; Douglas Jones, who brought greetings from the Technical Section of the Canadian Pulp and Paper Association; Ray De Montigny and Ken Logan of Canadian Pulp and Paper Association. J. Richter Salvesen introduced the speaker, Borje Steenberg, of the Swedish Forest Products Research Institute.

Mr. Steenberg spoke on "The Principles of Screening System Design." The presentation included a theoretical approach to problems of screening based on the concept of a charge in any system being a charge divided into an "accept" and "reject" portion. He pointed out that perfect separation is not compatible with reasonable production goals. The degree of productive separation is dependent on the time of residence, degree of dilution, and amount of turbulence or agitation of the material being screened, as well as geometry of the screening device.

The presentation pointed out that rules of good screening require (1) multiple stages for satisfactory rate with adequate cleanliness, (2) connection of streams of stock of like cleanliness independent of consistency, and (3) minimizing of water flow in the system.

Mr. Steenberg pointed out that his presentation included portions of several papers which will be published in the near future. In view of the pending publication on the studies discussed and since the evening's presentation included excerpts of a number of studies, no paper on Mr. Steenberg's talk is available.

JOHN W. BARD, *Secretary*

Kalamazoo Valley

Kalamazoo Valley Section met for a dinner meeting at the Hotel Harris, Kalamazoo, on September 30, and the speaker was A. H. Nissan, research professor of wool textile engineering, Dept. of Textile Industries, Leeds University, England, formerly technical director and member of the board of Bowaters Development and Research Ltd. Mr. Nissan's subject was "An Analytical Approach to the Problem of Drying of Thin Fibrous Sheets on Multi-Cylinder Machines." This was also the paper he presented before the Maine-New Hampshire Section. J. A. Dean, chairman of the Local Section presided. R. T. Trelfa was in charge of the program; about 90 attended.

A. H. Nissan, Research Professor of Wool Textile Engineering, Department of Textile Industries, Leeds University, England

The paper was very well received and caused a stimulating discussion, in which Mr. Nissan's fundamental approach contrasted with observations from practical experience, one serving to interpret the other. It was generally agreed that

R. P. Whitney and J. A. Van den Akker, The Institute of Paper Chemistry; H. C. Crandall, Mosinee Paper Mills Co.; K. C. Logan, Northeastern Paper Products, Ltd.; G. F. Underhay, Bowaters Development and Research Ltd.; Borje Steenberg, Swedish Forest Products Research Laboratory; L. A. Moss, Whiting Plover Paper Co.; J. R. Salvesen, Marathon Corp., R. G. Macdonald, TAPPI; Raimbault de Montigny, E. B. Eddy Co. Ltd.; and Douglas Jones, CPPA

J. A. Dean, chairman of the Kalamazoo Valley Section and A. H. Nissan

A. H. Nadelman, Western Michigan College, A. H. Nissan, Leeds University, England; R. T. Elias, Western Michigan College

Local Sections might do well to have more meetings of this fundamental type.

ROBERT T. ELIAS, *Secretary*

An Analytical Approach to the Problem of Drying of Thin Fibrous Sheets on Multi-Cylinder Machines-Abstract

A. H. Nissan

THE speaker, with his colleague, W. G. Kaye, set out to follow the paper web from the instant it first touches a drying cylinder until it finally emerges from the last drier and to calculate its temperature and moisture content at every point of its path. In this there were three difficulties to be resolved: (1) the process was found to be physically an extremely complicated one, (2) the mathematical treatment was likewise an involved system of differential equations which could not be integrated readily, and (3) many of the parameters which the treatment demanded were not known with sufficient accuracy.

To overcome these difficulties it was found necessary to introduce several simplifying assumptions and to use some "intelligent guesses" in choosing the value of parameters or of certain functions. The device was also employed of dividing the drying section into successive "cycles" each consisting of one cylinder and the space between it and the next succeeding cylinder. The cycles themselves were then divided into four phases or zones. Phase I began with the paper touching the cylinder and ended when the felt first touched the paper. Phase II followed phase I and ended when the felt parted from the paper. Phase III followed and ended when the paper left the cylinder. Phase IV comprised the period when the paper was in free air between cylinders. Calculations were made for each phase separately and in this way sufficient simplification was introduced to make the equations manageable.

Having obtained relatively simple formulas, these were then applied to calculate what took place in a machine running at 900 f.p.m. making newsprint and magazine paper. Calculations were made successively for each phase of 35 cycles and the temperature, average water loss per phase and per cycle, and the sheet water content were calculated for the entire length of the drying machine.

In view of the many assumptions and simplifications made in deriving and applying the equations, the validity of the method and of the results obtained had to be established before they could be usefully discussed. It is concluded that the calculations are valid in so far as giving the values to be obtained average over a period of time and also averaged for the whole width of the sheet. Without further exact knowledge it is not possible to calculate the values obtaining at a particular point across the machine and at a particular time.

The curves obtained by means of these equations are then discussed in some detail. The temperature of the sheet follows a zig-zag pattern of continuously changing dimensions. The temperature curve starts with a large upswing and a small downswing in the first cycle; the upswings tend to decrease and the downswings to increase until they equate (about the fifth cylinder) and keep equal for a few cylinders; then both begin to increase and the over-all temperature swings get increasingly wider till about two thirds of the way down the drying section; after that the downswings begin to decrease and the average and maximum temperatures steadily rise; finally both up and downswings decrease in magnitude to give a relatively small oscillation in temperature when the sheet is near the end of the drying section of the papermaking machine.

The rate of water loss per phase and per cycle show similarly continuous changes. The rates rise with each succeeding cycle at an increasing slope until they reach peaks nearly two thirds of the way in the drying section when they begin to decrease until they level off at very low values. A discussion on how to increase the over-all rates of water removal suggests that improvements may be achieved in the earlier parts of the drying section by improving the rate of heat transfer, by using higher steam pressures, or by blowing air in opposition to the flow of the sheet. All these factors, however, are limited by economic or papermaking considerations.

A. H NISSAN, Research Professor of Wool Textile Engineering Department of Textile Industries, The University, Leeds, England.

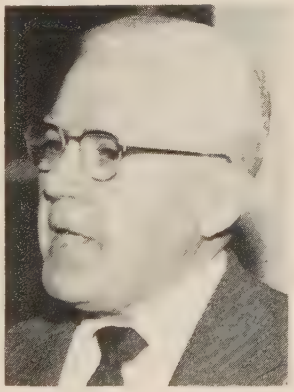
Scene in Hotel Harris, Kalamazoo, during the meeting of the Kalamazoo Valley Section, Sept. 30, 1954

Finally, it is noted according to the analysis, that although the sheet spends 60% of its time of drying in phase II, little or no water actually leaves the sheet in phase II when the felt covers the sheet. At least, the total drying can be accounted for by the evaporations that the calculations show to take place in phases I, III, and IV when the sheet has a minimum of one side exposed to the air. This fact, in itself, would have been of little significance because the major rise in temperature of the sheet, which is the root cause of the drying action of the section, takes place in the second phase. (Thus, the felts are contributing to the drying—even according to the analysis—by ensuring a high rate of heat transfer.) What makes this finding significant is that it is in conflict with previous experimental findings by Sherwood and his co-workers and by Smith and Attwood that as much as 60 to 80% of the total loss of water in the early parts of the drying section must take place when the felt covers the sheet. These experimental observations were made on slow-speed machines, and there is strong evidence that the water must leave the sheet in the liquid state. Consequently, it is suggested that on medium and high-speed machines the felts must be in a set of conditions which are not conducive to liquid absorption (and later evaporation from the felts). It is therefore recommended that an increase in the rate of drying of a machine may be achieved if a new type of felt is developed with particularly enhanced water absorbing properties on one side and with an open texture on the other side, to facilitate evaporation, and if additional provisions were made to dry the felt between individual cylinders and before its return to meet the wet paper. Thus water would be removed mechanically from the very wet sheet and dried off the felt at a higher rate than is possible in drying the sheet itself directly. Again economic considerations would, of course, be the final arbiters.

Delaware Valley

The September meeting of the Delaware Valley Section was held in Chester, Pa., on Sept. 16, 1954. Through the efforts of Edward Molin, first vice-chairman, and Phillip Nethercut, second vice-chairman, a very interesting meeting was arranged.

A plant visit to the Scott Paper Co. in Chester brought out some 190 members and guests during the afternoon plant visit. The meeting was held at "The Clubhouse" in Chester and featured a welcoming address by J. L. Ober, vice-president of the Scott Paper Co., and a very interesting technical paper on the drying of paper which was presented by Alfred Nissan, professor of textile engineering at the University of Leeds, England.



J. L. Ober, Scott Paper Co.

Mr. Nissan's paper will be published in *Tappi*.

The next meeting of the Delaware Valley Section will be held on Dec. 10, 1954, at the Engineer's Club in Philadelphia. This meeting will consist of a panel discussion on "The Latest Developments in Beater Additives."

CARL F. ACKERMAN, *Secretary*

Empire State (Metropolitan District)

The first dinner meeting of the Metropolitan District, Empire State Section of TAPPI, was held at 6:30 p.m. on Tuesday, Sept. 14, 1954, at Fraunces Tavern in New York City. About 80 members and guests were present to hear an interesting paper presented by Walter L. Hardy, director of engineering for Foster D. Snell, Inc. on "Practical Examples in the Development of Paper Coatings."

M. M. Muntz receiving the Edward J. Albert Award Plaque from P. H. Glatfelter III, president of P. H. Glatfelter Co., at Spring Grove, Pa. Each year the Delaware Valley Section of TAPPI sponsors a competition among the younger members of the section for the best research paper. E. J. Albert, president of the Thwing-Albert Instrument Co., Philadelphia, is a charter member and past chairman of the Delaware Valley Section. Pictured (reading from left to right) are A. G. Dreis, F. J. Lovegren, M. M. Muntz, A. J. Luettgen, and P. H. Glatfelter III, all of the P. H. Glatfelter Co.

Mr. Hardy pointed out that the numerous raw materials now available to the coating formulator permit the production of practically limitless variations in the functional properties of coated and laminated papers. The big problem is often to arrive at some compromise when a series of functional properties are required in one sheet.

Mr. Hardy described briefly some of the new materials available and, in more detail, how they were applied to produce predetermined properties in the finished product. Included were methods to produce grease resistance, high and low water-vapor and selective gas permeabilities, wet strength, light resistance, and many other functional properties.

The talk was followed by an interesting question and answer period in which the economic factors affecting the use of these new materials was discussed.

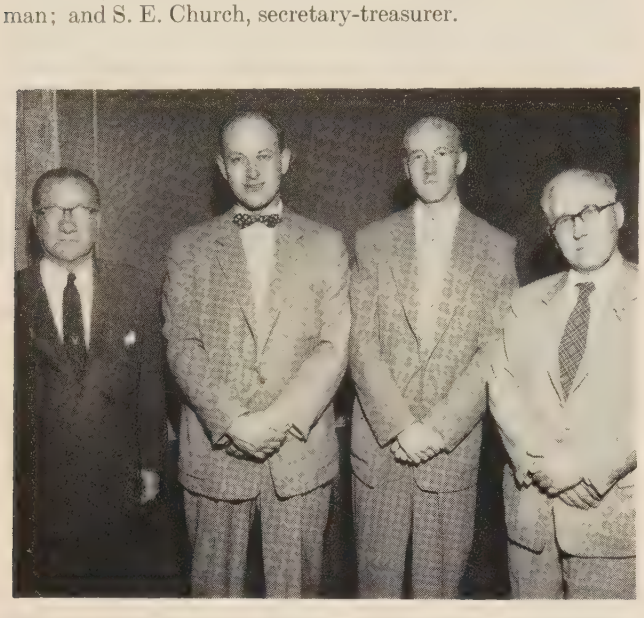
L. E. GEORGEVITS, *Publicity Chairman*

Some of the members of the Delaware Valley Section at "The Clubhouse," Chester, Pa.

Empire State (Central District)

The first Fall meeting of the Central District was held at the University Club with 124 in attendance.

The after-dinner program began with the introduction of the following persons at the head table: F. W. O'Neil, chairman; Durward Geffken, vice-chairman; Mr. and Mrs. Wilfred Gallay, director of research, The E. B. Eddy Co., Hull, Que.; Harry M. Gray, past chairman; H. D. Cook, past chairman; Fred Sommerville, Empire State Section chairman; and S. E. Church, secretary-treasurer.



Wilfred Galley, E. B. Eddy Co.; D. B. Geffken, Oswego Falls Corp.; F. W. O'Neil, College of Forestry, State University of New York; and H. M. Gray, Oswego Falls Corp.

Mr. Geffken introduced Mr. Gallay who spoke on "The Development of Strength on the Paper Machine" with particular emphasis on the nature of interfiber bonding forces and their effect on sheet strength development in the range of 15 to 40% solids content. He included a brief summary of their work on wet-web strength, which was first given at the February, 1954, New York TAPPI meeting. An additional paper given at the recent Symposium on the Fundamentals of the Paper Machine at Appleton, Wis., is expected to be published in the November and December issues of *Tappi*. The need for a more fundamental understanding of strength development was stressed, especially in regard to stock preparation. A brief discussion followed.

S. Earll Church, *Secretary-Treasurer*

Lake Erie

Following is a transcript of the talk given by L. W. Helmick of the industrial engineering firm of Helmick and Associates to the Cleveland meeting of the Lake Erie Section of TAPPI at the Carter Hotel, Cleveland, Ohio, at 8:00 p.m., Sept. 10, 1954.

Industrial Engineering Offers New Tools to the Paper Industry

L. W. Helmick

With the old type of incentives, generally of the piece work type, standards were set by past historical production, foremen's guess, or by time study.

The modern trend, of course, is to use time and motion analysis as a basis. Standards from these time and motion analyses are developed into tables called standard data. Standard data are the result of determining what causes the time to vary between one product and another, plotting the amount of difference and the cause of the difference on graphic charts, and establishing by element complete standard times covering all of the possible variations and specifications of material on a specific operation.

The method of establishing standard data by element necessitates an accurate analysis of all phases of the operation so that the labor utilization is greatly improved. In other words, any idle time is utilized where possible, the method of doing the work and the method of flow of material are studied at the same time that the actual time requirements are analyzed. This makes it possible to obtain a much higher degree of labor utilization and also to improve methods wherever such improvements can be made without major alterations. The major alterations, of course, are usually handled as an entirely separate proposition through request for capital expenditures.

Standards are expressed in terms of time rather than money because the amount of time required to perform work remains the same even though the rates may go up or down annually because of inflationary or deflationary economic conditions. The only time the standard time requires alteration is when the product, methods, or equipment are altered so that revision to the actual time required is justified.

Indirect labor is usually measured in either one of two ways: by direct output of the indirect worker, such as the time required per thousand pieces per skid handled, etc., or by a ratio of indirect hours to the direct hours serviced. For example, it may be found that one trucker should service ten machines. This can be determined by actual time study of the trucker so that there is an accurate measurement of the service time required for each operating machine. It is customary to use incentive for indirect workers so that it is made worth their while to render the best possible service to the maximum number of direct workers.

Production standards can be used in quite a wide variety of ways. The way we usually think of their use is for incentives to control the direct labor cost. This, of course, is the most immediate use that should be made and probably the most advantageous in many ways. However, it is also possible to use standards to determine what the actual costs are for each product and by this determination, it is possible to tell what the pricing should be and by adding the proper percentages, the profit of the operations can actually be controlled. This is something that is rather difficult to do without accurate standards so that what the costs are for each product can be determined correctly.

The standards can also be used to determine how long each product should take on each operation that it passes through for purposes of planning production. In other words, for scheduling the processing of orders through the plant, determining when they will be finished so the proper delivery date can be quoted to customers, determining the machine loading according to the capacity of the various equipment so that idle time in the manufacturing processes is sure to be minimized and so bottlenecks can be prevented by not scheduling too much material for a specific operation at any one time.

The standards can be used for two types of cost. Number one is the cost by product already mentioned; the other is the relationship of actual departmental manufacturing cost to the standard cost for the same work. This is very effective as a management operating tool to keep manufacturing costs in line with what they should be.

It is possible to set up budgets or supervisory cost control based on the past history of what the various controllable costs have been. This plan is used primarily with incentive to get the key personnel on the ball and have them do the very best job of controlling costs of which they are capable. This plan should be used as a group incentive so that all of the foremen work together as a team, working toward the common objective of a better operating cost picture. This is absolutely

essential because any other type of supervisory incentive will make each foreman try to shove bad material off on the foremen of other departments rather than working together as a team which is the desirable objective.

The supervisory incentive system is supplemented by meetings where the supervisors are induced to discuss their operating problems and try to reach a common solution, with every member of the group participating in trying to solve these problems. At these meetings cost figures are furnished to each supervisor so that they can discuss the cause of the cost picture on each item, trying to find a way of reducing each cost and automatically becoming very cost conscious. They also bring out their ideas for improvements to operations at these meetings. It is here that the good ideas for improvement are separated from the impractical ones, because the group is usually very critical of any suggestion made by any member so that the recommendations to management are usually boiled down to only those feasible, practical things which should be done. This saves management a lot of time. A record is made as minutes of each meeting so that all suggestions and ideas brought out can be followed up as necessary at following meetings. Thus no suggestion is ever lost or ignored until final disposition is determined. This does away with the attitude of "why suggest anything—nothing is ever done about it."

The next thing that usually occurs when it is decided that a better supervisory job is desired is that it is necessary to train the supervisors so that they are capable of doing a better job. The supervisory training should be divided into two parts. The first part is classroom instruction which is usually supplemented with both texts and sound motion pictures. There should also be a program of on the job training so that the foremen are instructed in the actual performance of the methods in which they are instructed in the classrooms.

One of the things that usually comes to light when we begin to train the foremen is that we do not have sufficient details on management policies. We will, of course, first ask ourselves: How do we want the foremen trained? What do we want them to do? As one example of this, many are familiar with the training program carried out by the Government during the last war which was called, "Training Within Industry," or "T.W.I." Under this program, there were three main courses. Number one was job instruction; number two job methods, and number three was job relations. Taking the case of the job instruction, this particular course told a foreman how to train a new worker. It started out by telling him how to put the new worker at ease. This was followed by selling him on the company for which he is going to work. Next was to take him out in the plant, show him the job, tell him how that job fitted into the total procedure and how important it was. Next, was the actual instruction which was composed of showing the man what to do, telling him how to do it, getting him to show and tell the supervisor how to do the job so he would be sure the man had learned. The old system of asking him whether he understood instructions, has been found impractical. Most people hate to admit that they have not understood anything. It makes it seem as though they lack intelligence and ability. They will usually say they understand and hope to muddle through somehow. Therefore, the next step of having the workman show the supervisor how to do the job and tell him how to do it is absolutely essential as a check to make sure he really understands. Following this, of course, is the gradually reduced supervision starting with very close and very quickly repeated supervision and tapered off as the worker acquires the necessary degree of skill and ability in the job.

Those who have seen this training put across to a group of foremen know that it is probably the best yet designed as a technique in teaching foremen how to train the new worker. Yet very frequently, this training covered only the foremen at the plant during the period of the last war and has not been repeated for the new foremen who have come into the operating picture since. The old foremen tend to forget it after awhile as any tool that is not used or strongly stressed apparently is bound to be neglected. The solution, of course, is that all of these practices should be incorporated into an instruction manual, wherein every foreman would be absolutely required to follow the necessary practices.

One part of this instruction was to have a foreman break down a job into elements, putting in written form exactly what he would tell the new worker to do. Almost universally, the foremen found that they actually didn't know the operation as thoroughly as they thought they did. They had to check and recheck many times before they could put the instructions into writing so that they knew and could instruct a worker in exactly how the job should be performed. Yet, despite how marked this became in the instruction classes, there are few companies who gave instructions to all of their foremen to make a written analysis of every job they supervised so that they would have this as a guide in the instructional work on all jobs under their control.

The policy manual should also include all of those things affecting the handling of improvements in methods, the practices the foreman has to follow in cost reduction, cost control, quality control, the handling of all types of problems in relationship to his personnel, such as uniform practices on discipline, handling of grievances, etc.

By listing correct practices on the handling of personnel the foreman knows just what he is to do in respect to all types offenses committed by workmen. A written manual authorizing the foreman that he should expect certain specified performance gives the management control of the conditions which can cause union radicalism.

Another extremely valuable tool of industrial engineering available in the paper industry is called, "job evaluation." We have a very general condition where the spread of rates between the lower skilled jobs and the higher skilled jobs are inadequate to offer incentive to workers to learn the higher skills. This is currently proving a difficulty to both management and unions. The unions, of course, have had a habit of asking for across-the-board increases. The spread which existed 15 years ago has been narrowed by the fact that the unskilled worker has received almost as much increase as the higher skilled worker. Job evaluation is the best method, or the author should say, methods (there are several systems in use) for analyzing what a job should be worth. This system, in general, is to break the job down into specific factors and analyzing each of them to determine the worth of a job. For example, the amount of physical effort is a factor, the amount of education required for learning a job is another. The experience in actual work on a job in order to acquire the necessary skill in performing that particular work is one of the important factors. Hazardous working conditions, responsibility for equipment, responsibility for loss of product, and other factors are considered. In analyzing these factors, one factor is taken at a time and every job in the plant is analyzed. For example, in considering physical effort, we would determine what is the most difficult job in the plant and what is the easiest job in the plant. In all other jobs we would assign a rating in between these extremes. After all ratings have been made for each factor, all factors are added together and the corresponding wage is determined.

There are several ways of putting the evaluated wage into effect. One method that need not be negotiated with any union is to use the evaluated wage for the payment of a standard hour in the incentive system. It has been determined that incentives are not a part of wages and working conditions and, therefore, can be handled unilaterally by management, without the union's agreement or without negotiating with the union.

Another method of putting the evaluated wage into effect is to negotiate with the union. This can be done by having

the union sit in on the evaluation committee, which is one very effectual way of doing it. It is usually necessary to consider the rates currently being paid to specific individuals in excess of the evaluated wage as what is called "red circle rates." These red circle rates are paid only to the specified individuals on the specified jobs and will eventually pass out of the picture. The easiest way to make them pass out of the picture quickly is to give no increases to any "red circle rates" but only on the actual evaluated job rates.

Another tool available to management in attempting to improve operations is the study of flow of material and the layout of equipment in the plant for this flow. The easiest way to analyze it is to make a drawing of the building on paper and to make cardboard templates of the size of all of the equipment and material which will be handled through the plant. With these cardboard templates and the drawing of the plant on paper, it is possible to move things quite readily at a minimum of expense. To do the same trial and error performance with the actual equipment would require many costly changes, wiring, foundations, and movement of the equipment itself. Most of the bugs can be readily worked out very quickly just with these cardboard templates.

R. L. Lewis

LETTERS TO THE EDITOR

Raw Materials for More Paper

To the Editor, *Tappi:*

With reference to the FAO Report (*Tappi* 37, No. 8: p. 14A–48a (Aug., 1954)), "Raw Materials for More Paper," there appear to be several misstatements concerning ramie fiber.

Ramie is a *soft* fiber, not a hard fiber (p. 31A).

The fibers in a ramie plant are not embedded in the leaves (p. 32A) but rather lie in a series of bast bundles extending the length of the stalk.

J. J. Osmar
Chicopee Mfg. Corp.
Milltown, N. J.

What is a Printed Publication?

To the Editor, *Tappi:*

In present-day patent practice, a patent shall not be granted for an invention which has been a printed publication for more than one year.

But what is a printed publication? Is a typed manuscript deposited in a public library a printed publication? The statutory law regarding a printed publication goes back to 1836, a date before the invention of typewriting.

In 1952 the Board of Appeals of the Patent Office ruled in *Ex Parte Hershberger* 96 USPQ 54 that a typewritten Ph.D. dissertation deposited in the University of Michigan library in 1940 was a printed publication. It is the purpose of the Patent Office, as well as of the Federal Courts, to uphold the law but is the Patent Office making law by such a ruling?

Typewriting is a form of writing as the name itself denotes. In writing or in typewriting one letter at a time is placed on the paper. It has been argued that the letters of a word in writing must be interconnected. Thus when one prints his name with a pencil, he in fact types it.

A publication in law means to make known to the public. A publication can thus be by word of mouth. A printed publication requires a printing and a publication. A book that is printed and never distributed, even as to a single copy, is not published.

It appears that the Patent Office decision cited above, placed too much emphasis on publication, and too little on the printed word. The decision implies that so long as the invention was made known to the public the manner of publication is secondary.

Such reasoning is especially bad in patent practice, since the law states that knowledge abroad, if not a printed publication, is not a bar to a patent to a second inventor here in the United States who had no information as to said foreign knowledge.

On the other hand, mere United States public knowledge of one year or more, even if not printed, is a bar to a patent. In other words, word of mouth public knowledge in the United States of an invention for more than one year is a bar to a United States patent but such unprinted knowledge in a foreign country is not a bar to a United States patent.

But a printed publication of one year or more prior to the filing of a United States application is a statutory bar even if printed in a foreign country in a foreign language.

It now appears that an obscure thesis deposited in an obscure foreign university or public library is a printed publication within the meaning of the law but wide or common knowledge of the invention in a foreign country, if not a printed publication, is not a statutory bar to obtaining a United States patent.

Frank Makara, *Patent Attorney*
233 Broadway, New York 7, N. Y.
Chairman, TAPPI *Patents Committee*

Correction

To the Editor, *Tappi:*

I found the article on "Semichemical Pulping Advances," by J. N. McGovern on page 152A of the May issue of *Tappi* most interesting. Like most mills we are most interested in pollution problems and the figures given in this article for pollution values are expressed in a way new to us.

I wonder if you would be good enough to explain what 200 p.p.m. per ton of pulp means? Does it mean that with the production of 1 ton of pulp per hour that the B.O.D. of semichemical spent liquor is 200 p.p.m., or is the relationship different?

W. T. Roberts
Thomas Owen & Co.
Cardiff, Wales

To the Editor, *Tappi:*

The article in question contained an error in the way in which pollutional values were expressed. On page 155A, column 1, paragraph 1, the last two sentences should read.

"Neutral sulphite semichemical spent liquor has a substantial pollutional effect. Its B.O.D. value, in terms of oxygen equivalent, ranges roughly from 100 to 300 lb. per ton of pulp produced, depending on pulp yield. This compares with 500 lb. for sulphite pulp and 50 lb. for sulphate pulp production."

J. N. McGovern
Parsons & Whittemore, Inc.
New York, N. Y.

Sixth Coating Conference

Statler Hotel,

Cleveland, Ohio

May 23–25, 1955

EMPLOYMENT SERVICE

Positions Open

CHEMIST

Excellent opportunity with a large progressive chemical company for an aggressive individual capable of introducing new chemicals and resins to the paper industry. Five to ten years' experience in paper converting required—sales experience desirable—paper schooling graduate preferred. Write giving résumé of education, experience, personal data, and salary desired. All replies remain confidential. Direct all replies to P401-54.

P406-54. Chemist or Chemical Engineer, 25 to 35, to be assistant pulp mill superintendent in expanding southeastern kraft mill. Please forward complete résumé giving past, present, and expected salary. All replies confidential.

P408-54. Paper Chemist for position with nationally known converter located in Metropolitan area. Background in plastics or adhesives desirable but not necessary. State age, experience, and salary desired. Write Box C 576, 300 W. 43rd St., New York 36, N. Y.

P409-54. Pulp Mill Superintendent for new board mill located in the South. Experience in the production of hardwood pulps made by the neutral sulphite semichemical process and a background of bleaching experience essential. Replies will be kept strictly confidential. Submit age, education, experience, present and past positions.

P410-54. Research and Development Supervisor qualified for growth to research directorship wanted to start as leader of existing group in stock preparation and paperboard manufacturing studies in diversified well-equipped research and development laboratory of major West Coast producer of paperboard, shipping containers, folding cartons. Location near San Francisco. Age 33–38 preferred.

P411-54. Mechanical Engineer for new and expanding pulp mill in Southeastern North Carolina. Must have had from 3 to 6 years' experience in the pulp and paper industry and be capable of doing layouts, design, cost estimating, reports, and engineering field work under general supervision only. Benefits include generous insurance, vacation, and retirement plans. Salary commensurate with qualifications. Please make résumé as complete as possible and submit a recent photograph.

P412-54. Salesmen, Chemist, or Chemical Engineer. New division of major chemical co. now staffing sales force for new products. Opportunity for rapid advancement to supervisory position for qualified men. Selling experience plus knowledge of high polymer material, paper coatings, waxes, etc., helpful.

P413-54. Research Man. Manufacturer of wood fiber products has opening for research man capable of heading up small development west coast plant. Excellent opportunity for progress. Write fully as to background and present status.

P414-54. Chemist. Leading paper converter offers excellent opportunity for chemist 25–35 years. Paper, adhesive, or ink experience required. Quality control background desirable. Supervisory ability essential. Duties not confined exclusively to laboratory. Metropolitan New York. Submit complete résumé including salary requirements.

P415-54. Salesman. Get the most out of your calls. You can handle our paper chemicals as a sideline. Very high commissions. Write for information. Your inquiry will be kept strictly confidential.

P416-54. Active agent wanted: Well established manufacturer of chemicals requires agent visiting regularly the paper industry in various territories.

P417-54. Excellent supervisory position available for technically trained young man in kraft paper testing laboratory. Location, Eastern Seaboard. Please submit complete résumé of education, experience and salary requirements in first letter.

Positions Wanted

E287-54. Pulp and Paper Technologist, 31, professional education and 5 years' experience in research, pilot operations, and production. Desire permanent responsible position in either operating or technical departments. Married with family.

Miscellaneous

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Needle Penetration of Petroleum Waxes*

Revision of TAPPI Suggested Method T 639 sm-53

(THIS SUGGESTED METHOD IS UNDER THE JURISDICTION OF THE WAX TESTING COMMITTEE)

This method covers a procedure for the empirical estimation of the consistency of waxes derived from petroleum, by measurement of the extent of penetration of a standard needle. Penetration of petroleum wax is the depth, in tenths of a millimeter, to which a standard needle penetrates into the wax under defined conditions. The sample is melted, heated to 30° F. above its melting point, and then cooled under controlled conditions to 77°F. The penetration is measured with a penetrometer by means of which a standard needle is applied to the sample for 5 seconds under a load of 100 grams. The method is applicable to waxes having a penetration not greater than 50.

APPARATUS

1. *Penetrometer.* For applying the standard needle to the surface of the specimen and for measuring the extent of penetration at the conclusion of the test.

The penetrometer shall be constructed in such a manner that the accurate placement of the tip of the needle adjoining the level surface of the specimen may be made while maintaining a zero reading on the indicator. The apparatus shown in Fig. 1 represents a composite drawing illustrating the two available types of instrument, that with an adjustable table, and that with an adjustable needle assembly; the use of either type instrument is permissible. The loaded needle must fall, when released, without appreciable friction. The instrument shall be provided with leveling screws and a spirit level to maintain the plunger shaft in a true vertical position.

2. *Timing Device.* An automatic timing release mechanism attached to the penetrometer may be used. Alternatively, a stopwatch graduated in 0.1-second intervals may be used.

3. *Needle and Plunger.* The needle shall be made from a cylindrical steel rod approximately 50 mm. long and 1.00 mm. in diameter conforming to the requirements given in Fig. 2. After tapering, the point shall be "blunted" by grinding off to a truncated cone. The finished needle shall be hardened and highly polished. The exposed length of the needle, when mounted in the chuck of the penetrometer or in a ferrule, shall be 41.5 ± 1.5 mm. The total weight of the plunger shall be 47.5 ± 0.05 grams and that of the needle, 2.5 ± 0.05 grams; a weight of 50 ± 0.05 grams is required for mounting on the plunger.

Note: The National Bureau of Standards will measure and certify the accuracy of penetration needles in accordance with these permissible variations.

4. *Test-Specimen Container.* Consisting of a brass cylinder open at both ends, having a 1-inch inside diameter, $1^1/_4$-inch height, and $^1/_8$-inch wall thickness. To prevent slippage of very hard wax, a few screw threads or grooves shall be cut into the center part of the inside wall of the cylinder. The cylinder shall be placed on a base plate of brass or glass, wetted with a mixture of equal volumes of glycerine and water.

5. *Air Bath.* Capable of being maintained at 77 ± 2°F. (*see* note following).

6. *Water Bath.* Of at least 10-liters capacity capable of being maintained at 77 ± 0.2°F. It shall be possible to immerse the test specimen in the bath to a depth of not less than 4 inches and to support it on a perforated shelf not less than 2 inches from the bottom of the bath. The bath shall be equipped with a circulating pump to supply the test bath used while observing the penetration, and to maintain a uniform water temperature.

Note: Alternatively, the use of a constant-temperature test room or an air cabinet, instead of the air and water baths and the test bath, is permitted, provided the temperature is maintained at 77 ± 0.2°F. Likewise, a box made of transparent plastic may be used for the water bath and the test performed directly in the water bath instead of in the test bath described below.

7. *Test Bath.* A container with minimum inside diameter of $3^1/_2$ inches and minimum inside depth above the bottom of $2^1/_8$ inches. It shall be made of a material having poor heat conductance, such as a wooden box lined with copper, or a glass or plastic container. Water from the water bath shall be circulated through this test bath so that its temperature is equal to that of the water bath. Provision shall be made to allow lowering and raising of the water level.

8. *Thermometer.* For use in the water bath. An ASTM Saybolt viscosity thermometer having a range of 66 to 80°F. and conforming to thermometer 17 F as given in ASTM Specification E1 is recommended. The thermometer shall be immersed to the 70°F. mark.

* This revised method is suggested by the Standards Committee as being the most suitable to date. It is *not*, however, a TAPPI Standard. Criticisms are earnestly requested and should be sent to R. G. Macdonald, Secretary, Technical Association of the Pulp and Paper Industry, 155 E. 44th St., New York 17, N. Y.

The method is essentially the same as ASTM Method D 1321–54 T.

TEST SPECIMEN

Heat the wax sample to 30°F. above its melting point (*see* TAPPI Standard 630 m), using care to prevent local overheating. Stir until homogeneous and

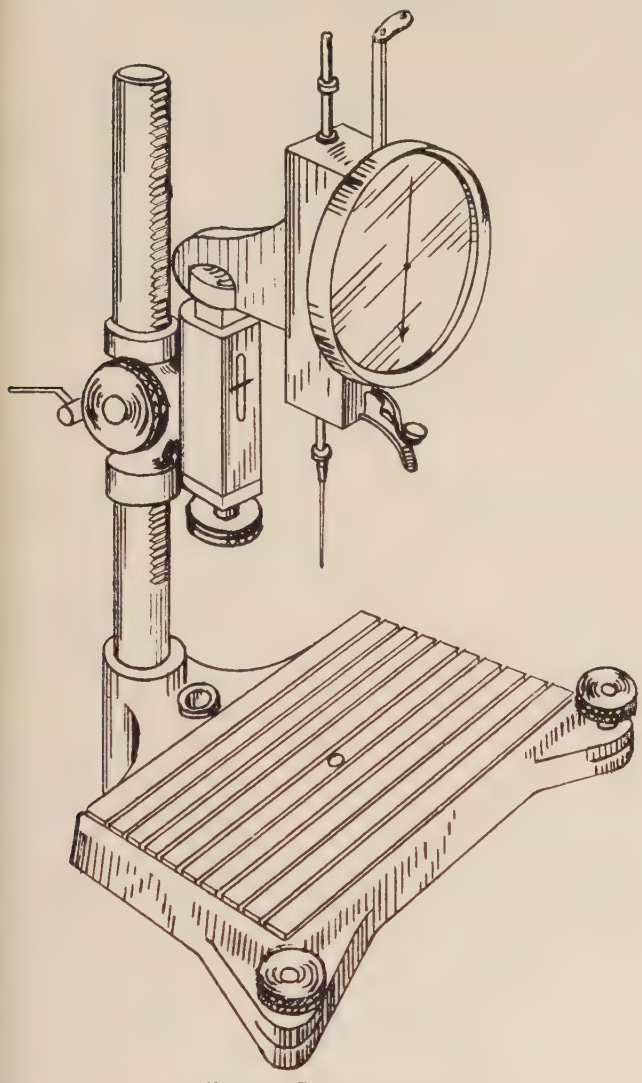

Fig. 1. Penetrometer

free from air bubbles; then pour into the test-specimen container in such a way that a convex meniscus is formed. Allow the container and contents to cool in the air bath at 77 ± 2°F. for 1 hour; then place in the water bath at 77 ± 0.2°F. and allow to remain for 1 hour.

PROCEDURE

Remove the test specimen from the water bath and slide the brass cylinder containing the test specimen off the brass plate; use the surface that contacted the plate for testing. Place the specimen in the test bath maintained at 77 ± 0.2°F. Adjust the water level in the test bath so as to cover the specimen completely.

Note: Very hard waxes occasionally will shrink away from the walls of the test-specimen container. In such cases it is permissible to wedge the wax in the test-specimen container.

The test temperature may be other than 77°F. but should not be so high as to give a penetration value exceeding 50.

Place the test bath with specimen upon the penetrometer table, making certain that it cannot teeter during testing. Keep the needle in the test bath for at least 5 minutes before attaching it to the penetrometer. Place a 50-gram weight above the needle, making a total load of 100 ± 0.15 grams for the zero position. Lower the water level in the test bath until the surface of the specimen is no longer covered with water. If a transparent thermostated box is used, the needle can be positioned without lowering the water level. Adjust either the indicator assembly or the table, depending upon the type of instrument, until the tip of the needle nearly touches the surface of the specimen. Securely lock the movable assembly in this position.

Then, by means of the slow-motion adjustment, bring the needle tip to just touch the surface of the specimen, watching the shadow of the needle tip as an aid to accurate setting. Raise the water level in the test bath until the specimen is completely covered. After 5 minutes release the needle shaft and hold it free for 5 seconds, timing this interval automatically or with a stopwatch graduated to 0.1 second. Observe that the release mechanism does not drag on the shaft; then gently depress the indicator shaft until it is stopped by the needle shaft, and read the penetration from the indicator scale.

Note: If an automatic timing mechanism is not used, the timing can be done conveniently by starting the watch before the beginning of the test, releasing the needle shaft as the second hand crosses a unit graduation of the watch, and engaging the shaft of the needle when the watch indicates exactly 5 seconds later.

Make four tests at points about equally spaced (not less than $^1/_2$ inch apart) on a circumference at least $^1/_8$ inch from the side of the container. Before each

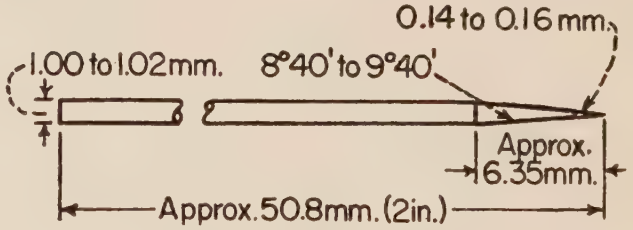

Fig. 2. Standard needle

test, wipe the needle carefully toward its point with a clean, dry cloth to remove all adhering wax, and position the needle as described above.

REPORT

Record as a single test value the average scale reading for the four penetrations on the prepared specimen and report to the nearest penetration unit. If a temperature other than 77°F. is used, give the actual temperature in the report.

PRECISION

The following data should be used for judging the acceptability of results (95% probability):

(a) Replicate results by the same operator using the same apparatus should be considered suspect if they differ from their mean by more than 2.

(b) The result submitted by one laboratory should be considered suspect if it differs from the mean of other laboratories by more than 3.

ADDITIONAL INFORMATION

In this revision the scope has been limited to waxes having a penetration not greater than 50, the section on Apparatus has been reworded and clarified; and a new section on Precision has been added.

Particle-Size Distribution of Coating Clay

*TAPPI Suggested Method T649 sm-54**

(THIS SUGGESTED METHOD IS UNDER THE JURISDICTION OF THE NONFIBROUS MATERIALS TESTING COMMITTEE)

PARTICLE-size distribution is particularly significant with respect to the performance of clays in paper coating. Sedimentation methods having as their basis Stokes' Law have found general acceptance for particle-size measurement. These methods give results expressed in terms of "equivalent spherical diameter"—the diameter of a sphere having the same specific gravity as the particle in question and settling at the same rate. Clay particles are nonspherical, but despite any uncertainty as to the relationship between equivalent spherical diameter and actual dimensions, the results of a sedimentation analysis can be readily correlated with some aspects of coating performance. Procedures limited to gravitational sedimentation are relatively inaccurate for clay particles below 1 mu in equivalent spherical diameter, and centrifugal procedures(*1*) are recommended for this extreme fine range. Nevertheless, the data obtainable by the gravitational method here described provide valuable information concerning papermaking clays.

APPARATUS

1. *Balance.* Sensitive to 50 mg.

2. *Stirring Apparatus.* A mechanically operated stirring device consisting of an electric motor suitably mounted to turn a vertical shaft at approximately 10,000 r.p.m., the shaft being equipped with a $^3/_4$-inch diameter impeller, and a dispersion cup about 7 inches deep and tapered from a diameter of about 3.75 inches at the top to about 2.5 inches at the bottom, and containing a vertical baffle about 1 inch wide extending from the top to the bottom of the cup on one side, to minimize vortex formation. This type of stirrer is commonly known as a "malted-milk mixer," and a satisfactory model is designated as Hamilton-Beach No. 30.

3. *Hydrometer.* Graduated (A) in grams of soil per liter and having a range from −5 to +60, or (B) in specific gravity and having a range from 0.995 to 1.038. The hydrometer bulb length is 139 mm., the bulb diameter is 30.5 to 32 mm., and the over-all length is 280 mm. Satisfactory hydrometers, designated as "Soil Hydrometers," are obtainable from Taylor Instrument Co. under catalog number 22297 for scale A and 22298 for scale B.

4. *Cylinders.* Inside diameter about 2.5 inches and 17 inches high, graduated to hold 1205 ml.

5. *Thermometer.* Accurate to 0.5°C. over a range of 15 to 35°C.

6. *Water Bath.* Of size to accommodate the graduated cylinders immersed to the 1205-ml. graduation. It should be capable of maintaining the water constant within ± 1°C. over a range from 18 to 30°C. and should include means of circulation of water to avoid localized temperature variation.

7. *Timing Device.* A stopwatch, or the equivalent, and an ordinary watch or clock.

REAGENT

Dispersing Agent. A 3.5% solution of tetrasodium pyrophosphate in distilled water.

TEST SPECIMEN

The test specimen shall consist of the equivalent of 40 grams of moisture-free clay, obtained according to the sampling procedure described in TAPPI Standard T 645 m.

PROCEDURE

Fill the dispersion cup to about 2 inches from its top with distilled water and add 6 ml. of dispersing agent.

Note: The validity of the test results is dependent upon obtaining complete deflocculation of the test specimen so that particles may settle as individuals. The quantity of dispersing agent specified is satisfactory for clays received in the usual form. In the case of clays obtained in "predispersed" condition, add 3 ml. of dispersing agent.

Weigh out the equivalent of 40 ± 0.05 grams of dry clay. (In the case of clays in the predispersed form weigh out 40.15 ± 0.05 grams of dry clay or its equivalent.) Preliminary accurate moisture determination on a separate portion or drying of the specimen at 80 ± 2°C. to constant weight is necessary.

Transfer the clay to the dispersion cup and mix with the mechanical stirring apparatus for 10 minutes at high speed. Loose agglomerates or flocs must be broken up to permit individual particles to settle as such, but it is equally important that mechanical attrition of individual particles be avoided. Ten minutes in the stirring apparatus are suitable for normal paper-coating clays. In the case of some very coarse clays, however, intense mechanical agitation must be used with extreme caution, if at all.

Transfer the suspension to the graduated cylinder, rinsing the dispersion cup into the cylinder; and finally dilute to 1205 ml. with distilled water at the same temperature as the water bath. Mix the suspension in the cylinder by inverting and shaking, using the palm of the hand as a stopper over the mouth of the cylinder. Place the cylinder in the constant-temperature bath and stir the suspension occasionally with a glass rod to prevent sedimentation. Also, prepare a cylinder containing a blank or control solution by diluting 5 ml. of dispersing agent to 1205 ml. with distilled water. Place this cylinder in the water bath together with the

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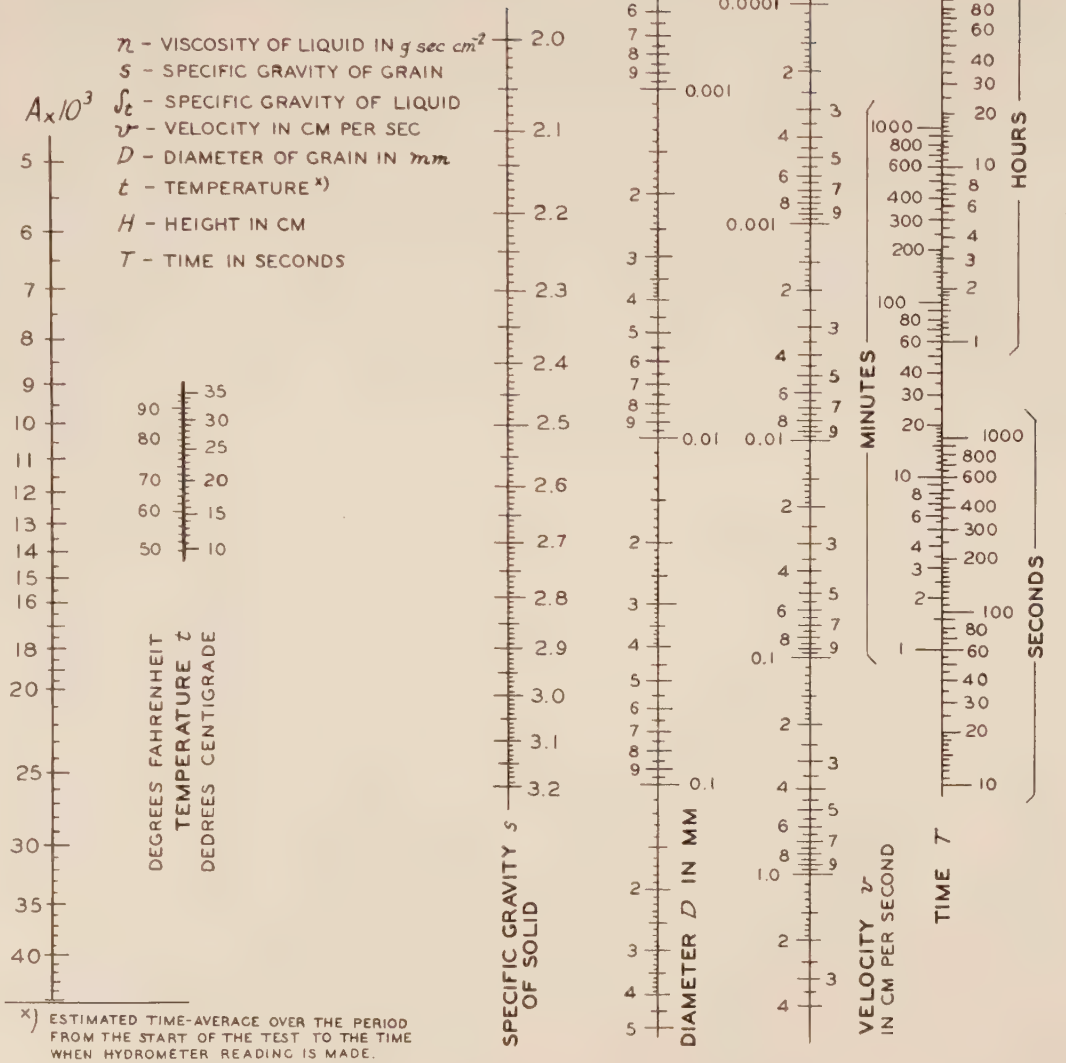
NOMOGRAPHIC CHART FOR SOLUTION OF STOKE'S LAW

n – VISCOSITY OF LIQUID IN $g\ sec\ cm^2$
s – SPECIFIC GRAVITY OF GRAIN
s_t – SPECIFIC GRAVITY OF LIQUID
v – VELOCITY IN CM PER SEC
D – DIAMETER OF GRAIN IN mm
t – TEMPERATURE x)
H – HEIGHT IN CM
T – TIME IN SECONDS



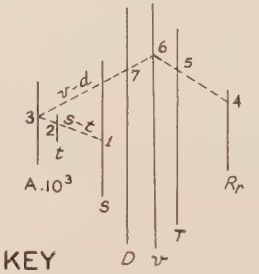
x) ESTIMATED TIME-AVERAGE OVER THE PERIOD FROM THE START OF THE TEST TO THE TIME WHEN HYDROMETER READING IS MADE.

STOKE'S LAW:

$$D = \sqrt{A \cdot v}$$

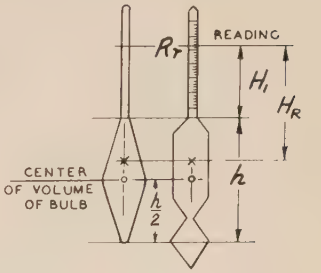
$$A = \frac{1800\,n}{s - s_t}$$

$$v = \frac{H}{T}$$



KEY

DESIGN OF (R_r) SCALE:



HEIGHT H_R WHICH CORRESPONDS TO READING R_r DETERMINED FROM

$$H_R = H_1 + \frac{1}{2}\left(h - \frac{\text{VOLUME OF HYDR BULB}}{\text{AREA OF GRADUATE}}\right)$$

CONSTANT

H TO BE DETERMINED FOR DIFFERENT VALUES OF R_r CORRESPONDING VALUES OF R_r TO BE PLOTTED ON RIGHT SIDE OF (HR_r) -SCALE AND CONVENIENT SUBDIVISIONS MADE.

FOR SOIL SUSPENSIONS IN WATER ANY HYDROMETER? MEASURING DENSITIES BETWEEN 0.995 AND 1.040 WITH AN ACCURACY OF 0.0002 MAY BE USED.

SUGGESTED: CALIBRATION AT 20°C IN DENSITIES. STREAM LINE BULB.
MAX H_1 = 14 TO 16 CM
h = 15 TO 17 CM.

FOR LIQUIDS OTHER THAN WATER THE (A)-VALUES MUST BE COMPUTED. THE (s) AND (t) SCALES APPLY ONLY TO SUSPENSIONS IN WATER.

cylinder containing the clay suspension and allow it to attain the temperature of the bath. When the suspension attains the temperature of the bath, remove the cylinder and remix the suspension by inversion and shaking as before. Immediately replace the cylinder in the bath and at the same moment start the timing device to obtain a record of elapsed settling time.

Note: The constant-temperature bath may be held at any point from 18 to 30°C. The nomographic solution of Stokes' Law (under Calculations) takes temperature into consideration.

Take readings with the hydrometer at such intervals that the total elapsed times form an approximate geometric progression. Suggested elapsed times are 1, 2, 5, 15, and 30 min., and 1, 2, 4, 8, and 25 hours. Read the hydrometer at the top of the meniscus, to the closest 0.1 if hydrometer A is used, or the nearest estimated 0.0001 if hydrometer B is used. In taking readings, insert and remove the hydrometer slowly, over a period of 10 to 15 seconds, to avoid unduly disturbing the suspension, and immerse the hydrometer to a point only slightly beyond that at which it floats freely. Remove the hydrometer after each reading, except the 1-minute reading, rinse and dry it; and insert it in the cylinder containing the solution of the dispersing agent at the same concentration as that containing the suspended clay. This solution serves as a blank and its hydrometer readings are used in the calculation of the results.

For each reading, record the elapsed sedimentation time, the temperature of the clay suspension, and the hydrometer readings for both the clay suspension and the blank solution.

CALCULATIONS

1. *Percentage of Clay in Suspension*

Calculate for each reading the percentage of dry clay remaining in suspension at the level at which the hydrometer measures the density of the suspension by the appropriate one of the following formulas:

For hydrometer with scale A:

$$P = \frac{(Rr - B)a \times 100}{W}$$

For hydrometer with scale B:

$$P = \left[\frac{100{,}000}{W} \times \frac{G}{G - B}\right] \times (Rr - B)$$

where

P = percentage
W = original concentration of suspension in grams per liter (for a sample of 40 grams dry weight in 1205 ml. of suspension, $W = 33.2$)
Rr = hydrometer reading in clay suspension
B = hydrometer reading in blank
a = correction factor (from Table I), since values on hydrometer scale A are computed on the basis of soil with a sp. gr. of 2.65
G = specific gravity of clay particles

Table I. Specific Gravity Correction for Hydrometer A

Specific gravity, G	*Factor, a*
2.95	0.94
2.85	0.96
2.75	0.98
2.65	1.00
2.55	1.02
2.45	1.05
2.35	1.08

Note: In the case of clays reasonably free from coarse particles, such as the usual coating clays, the above calculations for the initial hydrometer readings should give values of 100% for the percentage remaining in suspension. Variation from this figure may be due to inaccurate weight of the test specimen or volume of the suspension.

In practice, it has been found practical to take the value of $(Rr - B)$ for the initial reading to be a measure of the starting concentration. The percentage remaining in suspension for each subsequent reading then becomes simply the ratio of its $(Rr - B)$ value to the initial $(Rr - B)$ value multiplied by 100.

Readings taken during the first few minutes of sedimentation, however, are more subject to possible error from several causes than are subsequent readings. These causes include settling of coarse particles on the hydrometer bulb, failure to attain complete temperature equilibrium, and the possible presence of entrained air in the suspension. Of these, the last named is perhaps the most frequent source of error. Treatment of the suspension before mixing with a small amount of an anti-foam agent, such as a drop or two of pine oil, aids materially in obtaining reliable initial readings.

2. *Equivalent Spherical Diameter of Particles*

Calculate the equivalent spherical particle diameter corresponding to the percentage indicated by each hydrometer reading according to Stokes' Law on the basis that a particle of this equivalent spherical diameter was at the surface of the suspension at the beginning of sedimentation and had settled to the level at which the hydrometer measures the density of the suspension in the appropriate sedimentation time.

Casagrande's (*2*) nomographic solution of Stokes' Law offers a convenient means of calculating equivalent spherical diameter. The Casagrande nomographic chart is shown in Fig. 1. Its use requires calibration of the hydrometer in terms of the depth of suspension (Hr) for each hydrometer reading. The formula for this calculation for hydrometers graduated in specific gravity (scale B) is in the upper right corner of the nomographic chart. The hydrometer is calibrated for the elevation of the surface of the liquid. Actual hydrometer readings on the clay suspension are made at the top of the meniscus and for this reason should be adjusted by a meniscus correction, the corrected readings being used in the graphical solution of Stokes' Law. It has been found that the addition of 0.0003 to the observed specific gravity gives values closely corresponding to the reading at the surface level.

If hydrometer A is employed, the calculations are made with the Casagrande nomographic chart by the same procedure used with hydrometer B, except the calibration of hydrometer A in terms of the height of suspension (Hr) for each hydrometer reading (Rr) is determined from the equation $Hr = 0.42D$, where D is the distance in centimeters between hydrometer reading and bottom of hydrometer.

It has been found experimentally that for this hydrometer the effective height which determines the grain size is 0.42 of the distance from the top of the suspension to the elevation of the bottom of the hydrometer.

REPORT

The report shall consist of a graph made by plotting for each hydrometer reading the percentage remaining in suspension ("per cent finer than") against the equivalent spherical diameter, using semilogarithmic graph paper with the particle-size values on the logarithmic scale. State also whether hydrometer scale A or B was used.

LITERATURE CITED

1. Norton, F. H., and Speil, S., *J. Am. Ceramic Soc.*, 21: 89 (1938).
2. Casagrande, A., "Hydrometer Method for Determination of Fineness Distribution of Soils," Julius Springer, Berlin, 1934.

ADDITIONAL REFERENCE

Bouyoucos, G. J., "An Improved Type of Soil Hydrometer," *Soil Science* 76: 377–378 (1953).

Viscosity of Starch and Starch Products*

Revision of TAPPI Suggested Method T 637 sm-53

(THIS SUGGESTED METHOD IS UNDER THE JURISDICTION OF THE NONFIBROUS MATERIALS TESTING COMMITTEE)

This method is for measuring the viscosity of starch solutions or suspensions as determined on the referee viscometer of the Corn Industries Research Foundation. The viscosity is recorded automatically as a graph which gives viscosity characteristics during any desired period of cooking and cooling.

APPARATUS

1. *Corn Industries Viscometer*, with water bath, as shown in Fig. 1. (This is manufactured by Hayes Scientific Appliances, Urbana, Ill.) The water bath in which the starch is cooked is electrically heated and the temperature automatically controlled by a variable thermoregulator so that any preset temperature can be maintained constant. The dynamometer, which is of the pendulum type, is located in the recorder case. Supplementary weights are provided so that the recorder chart at full scale has four ranges of viscosity: 225, 450, 900, and 1800 gram-centimeters, respectively. Weights corresponding to each scale can be added or removed instantly without change in the calibration of the viscometer. This permits testing all starches over a wide range of concentrations. One advantage of this is that starches of widely different viscosities can often be tested at the same concentration so that a direct comparison can be made of their properties.

2. *Container*, of 1-liter capacity. An enameled graduate with handle is most convenient.

TEST SPECIMEN

A representative sample is required in accordance with Table I.

PROCEDURE

Determine the moisture content of the sample according to the procedure given in T 638 m.

Weigh out the starch sample in an amount (±0.1 gram) intermediate between the extreme concentration limits given in the table for the particular type of starch being tested. Transfer the starch samples to a 1-liter container and add sufficient distilled water at room temperature to make a total weight of 1000 grams of suspension. Make preliminary viscosity determinations as described below. If the concentration selected does not give a viscosity value at the end of the test within the range of 50 to 150 gram-cm. of torque, make additional tests at different concentrations to obtain a value within that range.

Table I. Starch Data

Kind of starch	*Concentration of Starch,[a] grams moisture-free starch per 1000 g. suspension*	*Supplementary weight on dynamometer g.-cm.*	*Approximate maximum viscosity to be expected, g.-cm.*
Corn, unmodified	40	225	50
	100	1800	1700
Corn, moderately thin-boiling	60	225	35 to 150
	110	1800	1200 to 1600
Corn, thin-boiling	70	225	35 to 80
	140	1800	1600 to 1800
Corn, very thin-boiling	180	225	50 to 150
	315	1800	1200 to 1800
Wheat, unmodified	50	225	50
	100	1800	1700
Tapioca, unmodified	40	225	175
	65	1800	1500
Potato, unmodified	40	225	175
	65	1800	1500

[a] These concentrations are approximations of the extreme limits of representative starches which can be tested in the Corn Industries Viscometer. All intermediate concentrations can also be tested.

Place the viscometer cup in the water bath heated to 92°C., unless results at some other temperature are desired. Insert the stirring device, swing the viscometer head in place over the cup, and attach the stirrer to the shafts in the viscometer head. Start the stirrer motor. Immediately before pouring the starch-water mixture into the viscometer cup, stir the slurry briefly with a stirring rod to suspend the starch uniformly. At the same time that the mixture is poured into the viscometer cup, start the chart-drive motor of the recorder. Cover the cup with the metal top to prevent cooling and evaporation.

For a hot viscosity determination, the test is entirely automatic. By arranging the conditions of the test, the viscosity characteristics of the starch are given by a continuous graph from which the following information can be read:

1. Time required for the initial viscosity rise and, by reading the thermometer in the paste, the temperature at this point.
2. Gelatinization range, the time and temperature change from the initial viscosity rise to the maximum viscosity.
3. Maximum viscosity.
4. Viscosity at all times during any desired period of cooking, thus showing the effect of heat and agitation.

* This revised method is suggested by the Standards Committee as being the most suitable to date. It is *not*, however, a TAPPI Standard. Criticisms are earnestly requested and should be sent to R. G. Macdonald, Secretary, Technical Association of the Pulp and Paper Industry, 155 E. 44th St., New York 17, N. Y.

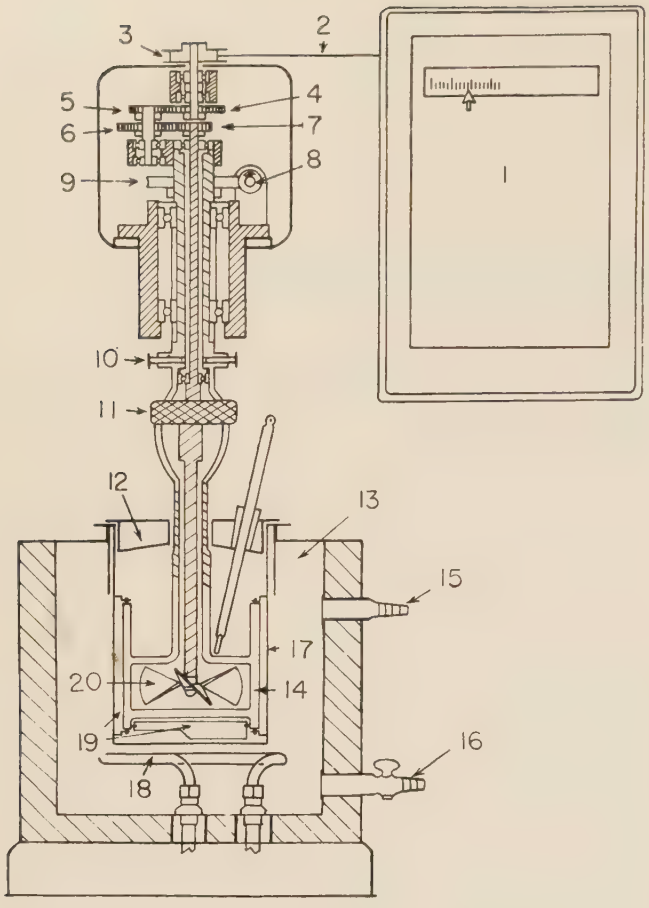


Fig. 1. Corn industries viscometer

1. Recorder and dynamometer (dynamometer not shown)
2. Cable from viscometer to recorder
3. Cable drum
4, 5, 6, 7. Gears of sun and planet differential
8. Worm, turned by synchronous motor (motor not shown)
9. Worm gear
10. Spring pins for holding center shaft
11. Coupling to attach stirrer
12. Condenser and cover
13. Water bath
14. Baffle
15. Overflow
16. Drain cock
17. Starch beaker
18. Electric heater, thermostatically controlled
19. Scraper blades
20. Propeller

Viscosities are given directly on the recorder chart in gram-centimeters of torque.

Note: For the effect of cooling on the viscosity of the paste, turn off the heater for the water bath after any desired period of cooking and circulate cold water through the water bath.

REPORT

Report the maximum viscosity and the viscosity at the end of 30 minutes in gram-centimeters of torque at 92°C., and state the concentration used. Other data may be included as desired.

ADDITIONAL INFORMATION

1. The viscosity of a liquid system is its resistance to flow. It may be regarded as fluid or internal friction. While starch solutions are often spoken of as having viscosity, they do not have a true (Newtonian) viscosity of a perfect fluid. The so-called viscosity of a starch solution is the combined effect of a number of inherent properties which cause it to deviate from Newtonian viscosity. These effects occur from the residual granule particles or from new colloidal groupings that take place as a result of cooking the starch. Many starches possess a varying degree of thixotropy, which is the property of becoming thinner with agitation or when under shear. In a starch paste, the observed viscosity depends upon the rate of shearing to which it is subjected in the viscometer; in a thixotropic paste, the greater the rate of shearing, the less the viscosity will be.

2. Viscosity data obtained for any starch are dependent upon the arbitrary selection of conditions of preparing the paste. Some types of starches reach a relatively stable viscosity, while with others the viscosity tends to decrease on continued heating, eventually reaching a value near that of water. The time required for these changes to occur varies with different types of starches and the same cycle of variation is evident even when the same starch is prepared in different concentrations. Also, some starches have a much greater tendency than others to form organized structures or gels on cooling, which increases the viscosity. Variables such as rate of heating, final maximum temperature, and rate and kind of stirring cause different observed viscosities. The method of sample preparation is thus very important and must be strictly observed if reproducible data are to be obtained, even with the same type of viscometer.

3. The principal change in this revision as compared to the previous method is in the concentration of starch suspension used in testing.

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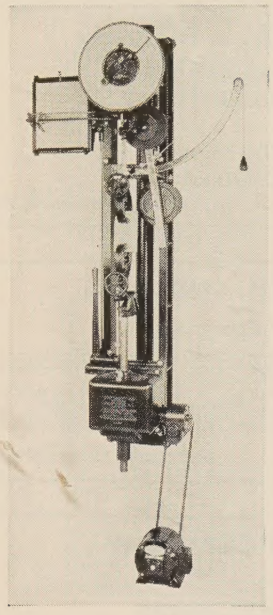

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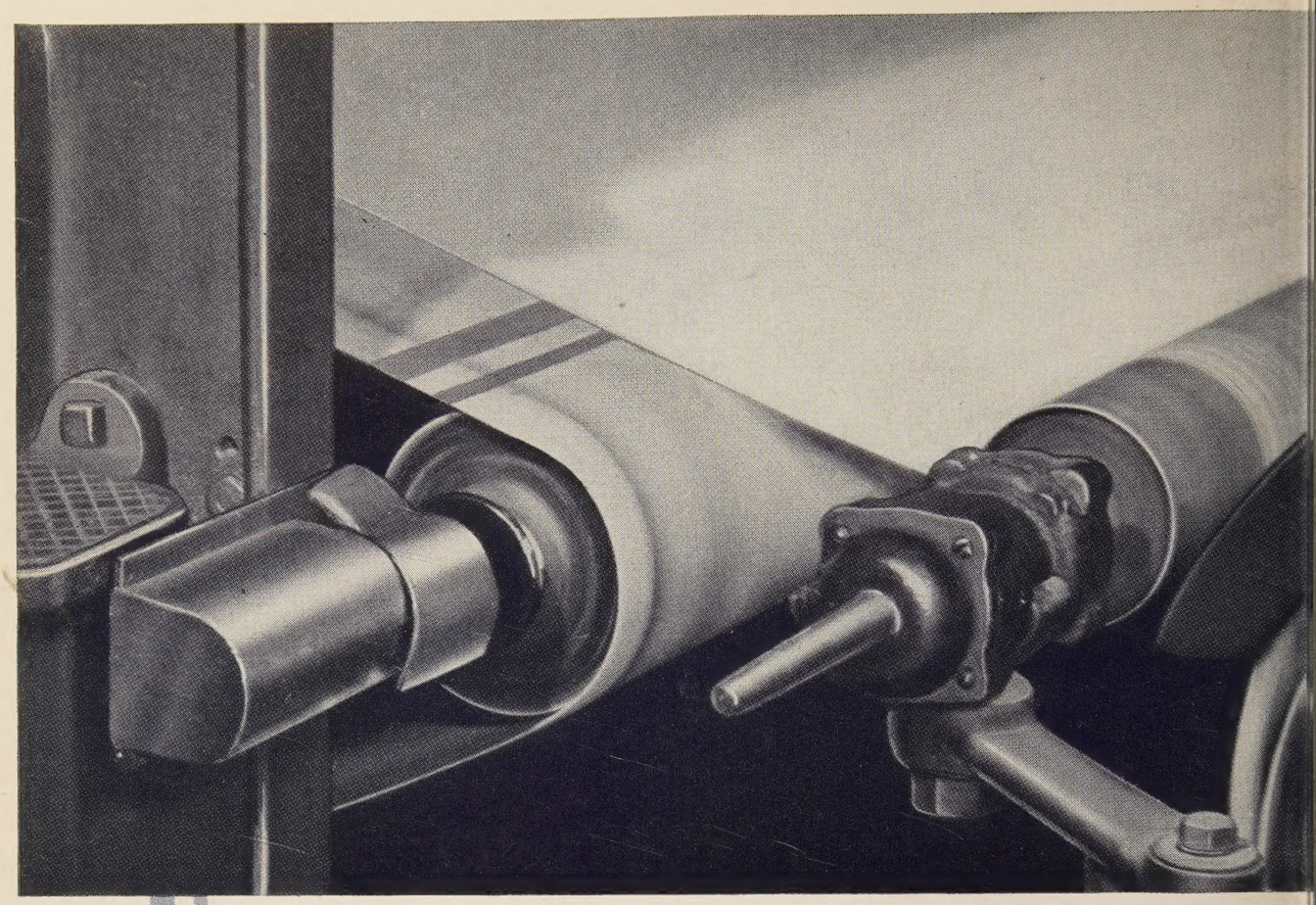

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